DOCUMENT RESUME

ED 211 364 SE 036 040

TITLE Measurement With Metric: A Resource Handbook. Revised Edition.
INSTITUTION Oregon State Dept. of Education, Salem.
PUB DATE [77]
NOTE 63p.; For related document, see ED 113 166.

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS Adult Education; Elementary Secondary Education; Instructional Materials; Laboratory Procedures; *Learning Activities; Mathematical Applications; *Mathematics Education; *Mathematics Instruction; *Measurement; *Metric System; Resource Materials; Teaching Guides
IDENTIFIERS *International System of Units

ABSTRACT

This document has been designed as a guide for anyone planning to teach the metric system to teachers, parents, children, or the general public. The handbook has the following sections: (1) Introduction, (2) Rationale and Key Considerations for Measuring with Metric, (3) Philosophy and Methodology, (4) Measurement Activities, (5) Teacher Workshops, (6) Metric Concerns for Parents, (7) Metric Program Implementation, (8) Glossary, and (9) Bibliography. The major premises and central themes for this handbook are: (1) Emphasis should be placed on measurement; (2) The hands-on approach is the best way to learn; (3) Estimation should be encouraged early and continued throughout learning experiences; (4) There is no need for exercises involving converting between systems; and (5) This document and workshops using it should demonstrate that effective measurement programs can be taught with low-cost materials. (MP)

MEASUREMENT . . . with Metric

A Resource Handbook

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FOREWORD

A changeover to the metric system of measurement appears to be inevitable in the United States. On Dec. 23, 1975, President Ford signed S. 100, The Metric Conversion Act of 1975. The act established a U. S. Metric Board to coordinate voluntary conversion to the metric system. The act officially defines "metric system" as the International System of Units (SI).

Most of the world is already using SI, in fact, the United States is the last industrial nation to adopt it. This transition is necessary if the U. S. is to maintain its national competitive position in world trade. Many U. S. businesses and industries are developing plans for the changeover, while others are already using the metric system to manufacture or measure their products.

Adults and children alike will appreciate the consistent interrelationships of the new system once they have become familiar with it. A special need during the transition years, therefore, will be to emphasize instruction in the most commonly used metric units.

In response to projected needs in Oregon, the State Board of Education adopted a resolution directing the changeover to the metric system in public school operations by 1983. *MEASUREMENT. . .with Metric* is part of our efforts to meet the Board's directive. For additional copies or for assistance is planning workshops in metric measurement, contact the Metric Coordination Committee here at the Department of Education.

Cordially,

Verne A. Duncan
State Superintendent of
Public Instruction

ACKNOWLEDGMENTS

This revised edition of *MEASUREMENT. . .with Metric* incorporates suggestions from those who evaluated the first edition of August 1974. Recommendations expressed in the Interstate Consortium on Metric Education (ICME) 1975 report have also influenced this revised edition. The Metric Coordination Committee worked with ICME in developing its recommendations.

An ad hoc Department of Education metric advisory committee, consisting of representatives of business, industry, teachers and administrators, has provided valuable assistance in developing plans for metrication in Oregon. On May 2, 1974, a "Measurement With Metric" conference was attended by professional educators as well as by leaders of business, industry and other groups. The conferees provided the basic philosophy for this handbook. The Metric Coordination Committee is indebted to the advisory committee and the workshop conferees for their contributions in developing plans for assisting schools in the transition to the metric system.

The committee also wishes to thank the State Textbook Commission for its endorsement of the State Board's metric conversion policy statement as it applies to criteria for the selection of instructional materials. Special thanks to Mrs. Marjorie Covey who served as conference reporter and assisted in the development of the handbook.

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1. INTRODUCTION

MEASUREMENT. . .with Metric has been designed as a guide for anyone planning to teach the metric system to teachers, parents, children or the general public. It includes measurement learning theory, technical information about the metric system and sample diagnostic and learning activities. The handbook presents one approach to the instructional process and can be used to teach all ages. It can be used as a complete guide or as a resource. The approach leads to and includes the use of the International System of Units (SI).*

The metric system offers several advantages in comparison with the present system. The set of multiples and submultiples of the base units is a decimal system compatible with the monetary and base-ten numeration systems being used. Furthermore, units of length, mass, area and volume are interrelated and are therefore easy to learn.

1.1 THEME FOR METRICATION

The ODE Metric Coordination Committee firmly holds that the five characteristics described below should be primary considerations in *all* efforts toward metrication. These characteristics are the major premise of this handbook—watch for each! In addition, these characteristics should be the central theme for all teacher in-service workshops on metrics, and for metric information workshops for parents or the general public. They should also be used in developing local district program guides for teaching the metric system.

1.1.1 Emphasis should be placed on measurement. Measurement is a basic concept in mathematics and has application in nearly all curricular areas. A developmental program based on sound learning theory is a primary consideration in successfully teaching measurement.

1.1.2 The "hands-on" approach is the best way to learn measurement. The "hands-on" activities should be learner-centered experiences that recognize the level of competence (readiness) of each individual and build upon and expand that competence. The use of appropriate experiences will gradually lead to the discovery of measurement concepts. They will also motivate the learner's interest and enthusiasm.

1.1.3 Estimation should be encouraged early and continued throughout measurement learning experiences. The idea is to estimate, record, then verify with a measurement. Some measuring experiences should be provided before asking students to estimate. No penalties should be given for poor estimates since this will discourage estimating.

1.1.4 While teaching measurement there is no need for exercises involving converting between systems. These are no more than rote drill exercises on multiplication and division. Evidence further indicates that such exercises actually delay the acquisition of the ability to THINK METRIC. (In the application stage some conversions may seem to be necessary. When this occurs, the use of charts, tables or calculators is suggested.)

1.1.5 This handbook and workshops using this handbook should both demonstrate that an effective measurement program can be taught with low cost materials. Some basic tools, homemade instruments, collected items and equipment borrowed from science supplies can provide a good activity centered approach at the early developmental levels. At the application levels, specialized measurement equipment may be needed in order to obtain the required degree of accuracy and precision. Some teachers have observed that learners who make and use their own measuring instruments get a "feel" for metric units more quickly.

*SI is the shortened form of Le Systeme International d'Unites.

2. RATIONALE AND KEY CONSIDERATIONS FOR MEASURING WITH METRIC

2.1 RATIONALE FOR GOING METRIC

The United States is going metric. The transition began in 1866 when the metre became the official unit of length. Americans have adjusted to the change slowly; however, during the last few years, they have begun to use the metric system much more frequently. Major United States industries are using metric measurements so that they can trade more easily with industries in other countries. The U. S. educational community has supported the transition taking place in American industries. Educators are helping to teach the metric system, which is a much simpler, more logical one, to industrial employees.

On December 23, 1975, President Ford signed the Metric Conversion Act of 1975. It declares that the changeover to the metric system is national policy. It also establishes a U. S. Metric Board to coordinate the voluntary changeover.

2.1.1. ADVANTAGES TO THE METRIC SYSTEM

The metric system has numerous features which justify its adoption as the official system of measurement for use in the U. S. The chief features are:

1. The metric system is developed on the same base-ten system as the numeration system used in the U. S.
2. The units of metric measurement form a logical system. Larger units are created by multiplying a base unit by appropriate powers of 10 (10, 100, 1,000, etc.). Submultiples are created by dividing a base unit by appropriate powers of 10 (1/10, 1/100, 1/1,000, etc.). This system avoids the difficulties involved in working with multiples of 12, 3, 5 1/2, 5280, etc.
3. The decimal nature of the metric system is used throughout. This permits greater use of decimal fractions and less use of common fractions.
4. All metric measurement units for mass, area and volume are based on metric units of length. Students find it easier to understand the relationships when they use the metric system than when they use the present nonrelated measurements.
5. The United States monetary system has the same decimal base as the metric system.

2.1.2. LEVELS OF SUPPORT FOR THE SYSTEM

The strengths of the metric system have long been recognized by other countries. The United States is among the last of the world powers to make the transition. The country has made great strides in the last few years.

In Oregon, more than 85 percent of surveyed businesses and industries support conversion to the metric system. They favor the transition despite the initial costs associated with changing over.

The State Board of Education is committed to a ten-year changeover period. On June 6, 1974, it adopted a resolution calling for conversion to the metric system in all phases of public school operation by 1983. The resolution also said that metric measurement should be the primary system of measurement used in textbooks as of November 1976. This resolution has the support of the Oregon State Textbook Commission.

Oregon school districts are now including an understanding of the metric system in their graduation requirements. They are doing this to better prepare students for the world in which they will live and work as adults.

2.2 COST OF CONVERSION

The cost to public school districts can be kept to a minimum. Textbooks using metric measurement as the primary system can be adopted in the normal pattern of textbook adoption. Additional supplies needed for teaching metric measurements are minimal. Many instruments, such as metre sticks and centimetre rulers and balances are already available in the

school's science supplies. Other materials can be made inexpensively at home. The process of making them can serve as an effective learning activity in itself.

2.3 EXPECTATIONS FOR THE CHANGEOVER PERIOD

During the years of transition from our customary system to the metric system, the rate of changeover will vary in different sectors of society. Some competence with both systems will be needed during this period. Probably the most efficient way to handle the transition will be to have two separate systems of measurement. The advantage of having separate systems is that all students will learn to THINK METRIC. People should be discouraged from relying on mental conversions between systems, as this may hinder rather than facilitate the adoption of a new system. Conversion requires an extra step and diverts attention from the new system.

The transition to the metric measurement system in packaging merchandise may occur in several stages. During the first stage, packages will show two sets of measurements, with the old system written first, e.g., "Net contents: one pound (454 g)." During the second stage, packages will also show two sets of labels, but this time the metric units will appear first and will reflect a convenient number, e.g. "Net contents: 500 g (17 5/8 oz.)." Only the metric units will appear by the third stage.

Much of retail trade is already in the first stage. A sixth grade class saw evidence of this in one Oregon city. Students found over 500 different products with dual labeling. Some companies had reached the third stage of labeling. Those which sold motorcycles, pharmaceuticals and photography equipment fell into this category.

2.4 SCOPE AND SEQUENCE

Teachers often ask, "What metric competencies and skills should be taught in grade __ ?". Clearly, teaching specific concepts in each grade will not help individual students who are either not prepared for them or beyond them. Hence, teachers need to diagnose each learner's development and readiness. Teachers can then plan activities to reach the comprehension level of each learner. The key is that each of the learning stages does not occur at a specific age even though these stages generally occur at approximately the same age for most youngsters.

Although a diagnostic approach avoids associating specific skills with specific grade levels, teachers may use some general guidelines in developing instructional programs. These guidelines take into account the sequential, developmental learning stages learning theorists have identified for learners. The following general guidelines were adapted from *Metric Competency Goals*, a report of the National Council of Teachers of Mathematics, Metric Implementation Committee.

Generally by the end of the primary level:

1. The child will be able to apply the general measuring process, using a model of a nonstandard unit to determine a measure. Example: The child can tell "about how many" sticks represent the length of a classroom.

2. The child will be able to use a centimetre ruler (centimetre markings only) to determine lengths to the nearest centimetre for distances equal to or shorter than the ruler.

3. The child will be able to select and use the appropriate type of unit and measuring instrument for specific measuring situations. For example:

Situation	Unit	Instrument
shorter lengths	centimetres	centimetre ruler
longer lengths	metre	metre stick, tape measure, trundle wheel
volume	litre	litre container
mass	kilogram	balance, bathroom scale
temperature	degrees Celsius	thermometer

4. The child will be able to include names of metric units and other metric expressions in his/her conversation.

5. Given models of a centimetre, a metre and a litre and other choices substantially larger and smaller than each, the child will be able to select the correct unit model.

6. The child will be aware that objects are commonly measured in specific units.
   Example: Q. What is bought in litres? A. Milk, juice, gasoline.

7. The child will be able to comprehend metric language as it is encountered in reading and associate names of units with their symbols.

8. The child will be able to read temperature from a Celsius scale and associate that temperature with specific experiences.
   Examples:
   - At -10° C it is "cold" outside,
   - At 0° C water freezes,
   - At 100° C water boils,
   - 30° C means "swimming" weather,
   - 20° C is room temperature.

Generally by the end of the intermediate levels:

1. The student will be able to demonstrate competency in the objectives listed above to the extent they are appropriate to his/her developmental level.

2. The learner will be able to use more units of the same kind than he/she did at the primary developmental level.
   Example:
   In addition to the centimetre and the metre, the student will be able to use units such as the millimetre and kilometre to measure length. He/she will be able to use millilitres to measure volume and grams to measure mass. The student will be familiar with common uses of such units.

3. The learner will be able to use numbers such as 10, 100, 1000, and later 0.1 0.01, 0.001, to convert measures in a given unit to equivalent measures in a related unit. The learner will be able to measure to the nearest tenth of a centimetre, metre, litre or kilogram.

4. The student's concept of unit size will improve for purposes of estimation. The student will be able to use previous experiences to decide whether an estimate is reasonable.

5. The student will be able to recognize and use symbols for the more common units.

6. The learner will be able to apply metric knowledge and skills in all areas of the curriculum.

7. The student will be able to demonstrate basic skills for reading measures on common metric measurement instruments.

8. The learner will be able to find more specific uses for more metric units than during the primary level. The individual will be able to give his/her own body measurements for mass, height, hand span or width of little finger.

9. The student will be able to choose appropriate units for measuring a variety of objects.
   Example:
   The student will be able to give the linear dimensions of a standard model of a square centimetre, square metre, cubic centimetre, cubic metre.

Generally by the end of the secondary level:

1. The student will be able to demonstrate competency in the objectives listed for both primary and intermediate levels, as appropriate to his/her age, maturity level and needs.

2. The student will be able to comprehend the prefixing system and change related units decimally. He/she will be able to read some measures directly in tenths, hundredths or thousandths of a metre, litre and kilogram.

3. The student will be able to comprehend the equivalencies 1 dm^3 = 1 l = 1000 cm^3 and 1 cm^3 = 1 ml. He/she will be able to comprehend and use correct symbols for square and cubic units.

4. The learner will be able to appreciate the metric system—the efficiency of the decimal nature of the prefixes, the use of decimal notations in recording measurements or computing them, etc. The student will also be able to appreciate the advantages of having mass, area and volume all related to length and to each other.

5. The learner will be able to master the use of those metric units and their symbols which consumers need; for example, metre, kilometre, centimetre, millimetre; kilogram, gram; litre, millilitre; degrees Celsius.

6. The student will be able to comprehend less frequently used measures such as the tonne (metric ton), kilolitre, milligram and hectare and some common, derived units such as km/h.

7. The student will be able to demonstrate estimation skills with common measures to a reasonable degree of accuracy.

8. The learner will be able to "think metric" in situations which call for a measurement in metric units.

9. The student will be able to use metrics to his/her economic advantage.
   Example:
   Given different prices which are based on different metric amounts of the same item, the student can determine the "best buy."

10. The student will know where to find information about the metric system.

Generally at the Post Secondary/Adult level:

1. Each person will be able to demonstrate competency in the objectives listed for all previous levels, as appropriate to his/her needs.

2. Each person will have the metric measurement skills necessary to perform successfully the specialty measurements required in his/her occupation or profession.

3. Each person can perform the necessary metric measurements and the computations necessary for informed purchasing of such items as food, clothing, fuel and real estate.

4. Each person has acquired sufficient metric measurement knowledge and skills to perform various life-coping skills: e.g., cooking from a recipe, computing gas consumption and travel distances, using metric tools and other household measurement devices, understanding metric measurements in weather forecasts and sports.

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3. PHILOSOPHY AND METHODOLOGY

The previous chapter was designed as a metric education program guide. Let us turn now to the teaching of measurement.

3.1 PHILOSOPHY OF TEACHING METRIC MEASUREMENT

The method for teaching measurement with metric suggested in this handbook—the "CONTINUOUS NONGRADED MEASUREMENT LEARNING APPROACH"—and the premise that concrete experiences ("hands-on") are the best way to teach measurement draw heavily on the learning theories of Jean Piaget, Barbel Inhelder, Richard Copeland, Robert Karplus, Herbert Thier and others. In the booklet, *Diagnostic and Learning Activities in Mathematics for Children,* Copeland reviews Piaget's learning theories and points out teaching implications. He then states:

> "The third and highest form of cognitive function is knowledge characterized as logico-mathematical. This knowledge develops in stages and is largely an internal process. It is not an acquired knowledge in the sense so many think of, the familiar stimulus-response sequence. This places the problem of 'teaching' logico-mathematical knowledge in a whole new context. Johnny may not be able to learn certain ideas regardless of how he is stimulated until a certain point in time when he has the necessary mental structures. Telling him about the transitive property, this is, if a=b and b=c then a=c, will have no meaning until he has the necessary thought processes and then the knowledge is almost automatic. The teacher then becomes a person who uses the verbal medium to ask questions rather than give answers.
>
> Another important function of the teacher is to provide an environment which allows the child to explore physically the objects around him. From actions performed, such as counting a row of objects in both directions, the child discovers the commutative property. In geometry he needs to physically explore shapes as a basis for the necessary abstractions."*

Karplus and Thier in *A New Look at Elementary School Science* also refer to Piaget:

> "This school of thought [Piaget's developmental learning stages] has two related central ideas: (1) children's intellectual capacity passes through a number of qualitatively contrasting stages before adulthood, and (2) a child's interaction with his environment plays a very significant role in his transition from one stage to the next."**

It is in this spirit that the strategies in this handbook are offered.

Teachers are encouraged to adopt programs based on both the basic concepts students need and each student's present level of readiness. The CONTINUOUS NONGRADED MEASUREMENT LEARNING APPROACH can help them design appropriate programs. This learning approach is nongraded in that students begin with concepts which they understand and then continue through subsequent learning levels in an orderly sequence. Because each child's understanding of measurement concepts is at a different level, it is important for the teacher to choose activities appropriate to each student's needs. Activities presented in the second section of this handbook may be used as diagnostic tools and/or as learning experiences.

3.1.1 MEASUREMENT LEARNING CHART

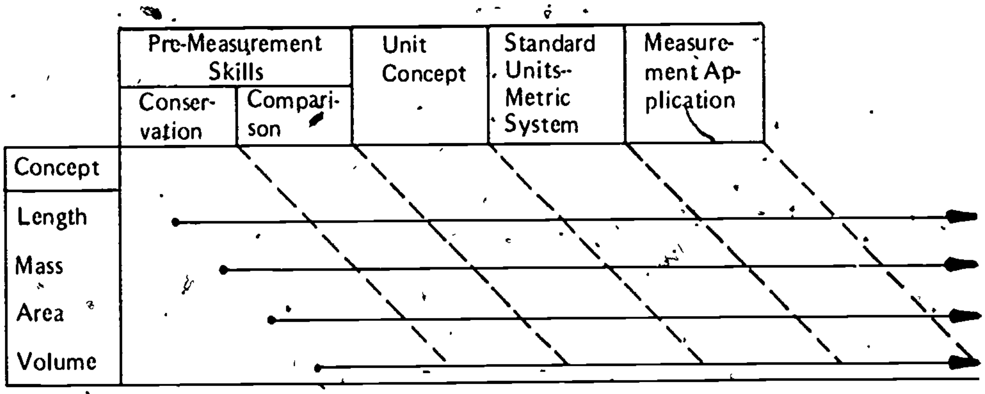
The following chart outlines the CONTINUOUS NONGRADED MEASUREMENT LEARNING APPROACH. It presents four major measurement concepts: length, mass, area and volume. A fifth concept, temperature, will be dealt with briefly later. The measurement concepts of time, money and angles should also be learned. Since these concepts are not directly related to the metric system, however, they are not presented in this handbook.

*Copeland, Richard W., *Diagnostic and Learning Activities in Mathematics for Children.* New York, Random House, Inc., 1974, Preface.

**Karplus, Robert, and Herbert D. Thier. *A New Look at Elementary School Science.* Chicago: Rand McNally, 1967, p. 21.

THE CONTINUOUS NONGRADED MEASUREMENT LEARNING APPROACH

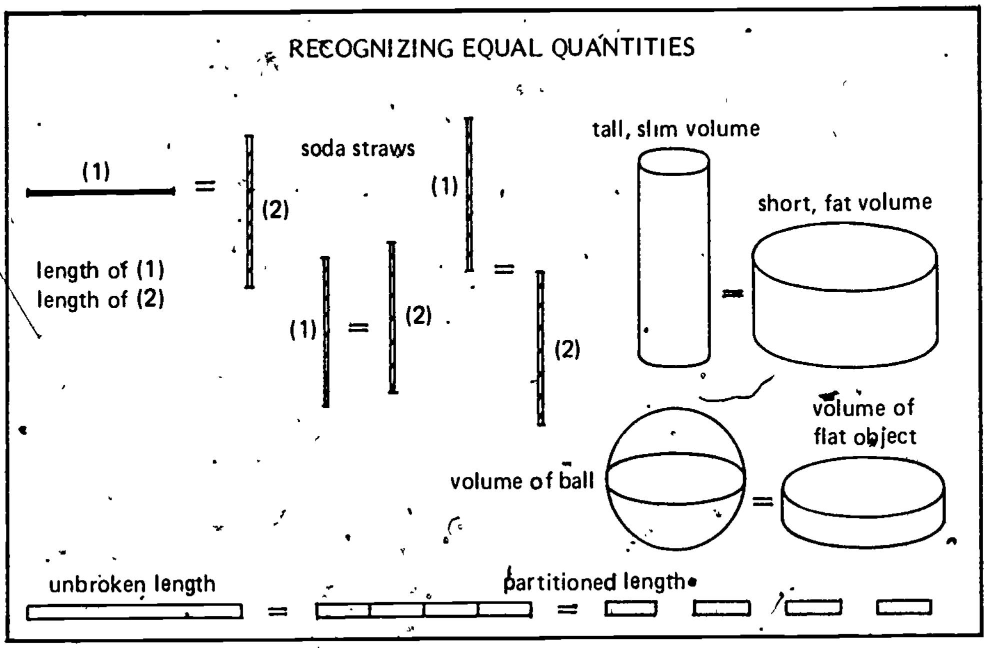
LEARNING LEVELS



The horizontal axis represents the sequence of learning levels. The vertical axis represents the measurement concepts (length, mass, area and volume) to be learned.

The concept of length should be introduced first, because other measurement concepts, especially in the metric system, are related to it. Students do not need to master all learning levels in length, however, before being introduced to mass, area and volume. The activities presented in this book will often lead to student progress in both the measurement concepts and the learning levels presented in the preceding chart. Students begin with the development of premeasurement skills and progress to nonstandard and standard measurement learning levels. The students may progress at their own learning rates through several levels of premeasurement and measurement. At any point, individual learners may be at different learning levels for each of the measurement concepts.

3.2 PREMEASUREMENT: CONSERVATION Learning theorists generally refer to a premeasurement learning stage as "conservation." The principle of conservation (constancy) of quantity states that length, mass, area and volume do not change when physical objects or materials are subjected to deformation, rearrangement or partitioning. This is a relatively advanced concept. It takes many "hands-on" experiences using manipulative materials before conservation of quantity is fully comprehended. Indeed, it is generally agreed that understanding this concept involves several stages of intellectual development.

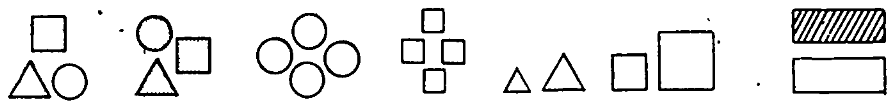


3.3 PREMEASUREMENT: COMPARISON

Measurement is a way of describing things, usually by comparing them to other objects. Recognizing similarities and differences between and among objects is the foundation on which unit measurement is built. At the beginning, a child may place two objects side by side to compare their lengths. Later, three or more object lengths may be compared in this manner. Eventually, the lengths of two objects may be compared by relating both of them to a third object.

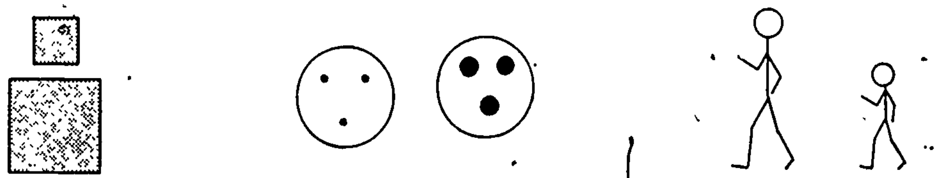
Simple comparison begins at a very early age and grows increasingly complex as learners develop skill in this area. Children should be encouraged to estimate relationships and then verify them by making actual comparisons of concrete objects. Penalties for poor estimates should be avoided as this will discourage students from trying.

- Qualitative Comparison: identifying objects which are similar in one or more properties, for instance, color, shape, texture, prettiness, hardness, flexibility.



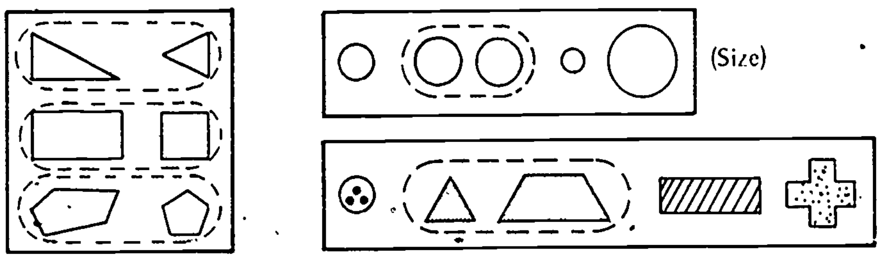
(Color) (Shape) (Shape) (Texture)

- Size Comparison: identifying objects that are larger, smaller, shorter, longer, etc.



(Size) (Size) (Size)

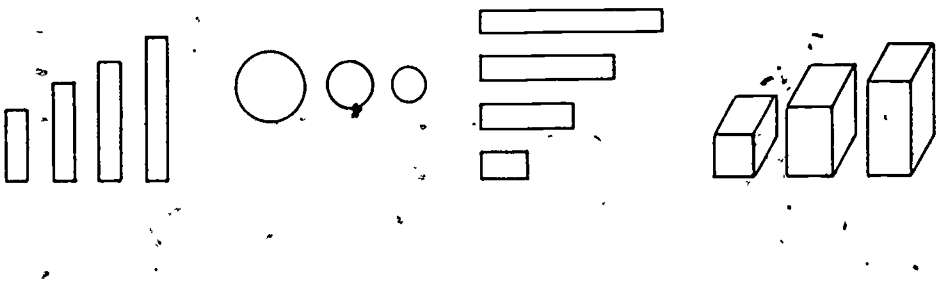
- Matching: recognizing objects that are the same in number, color, size, shape, texture, weight, or other characteristics.



(Size)

(No. Sides) (Color)

- Ordering: arranging various sized objects in a progression, for example, from the shortest to longest, largest to smallest, lightest to heaviest.



3.4 MEASUREMENT: UNIT CONCEPT

The skills and understandings of the two learning levels described above can be considered measurement readiness. Upon acquiring competence at the first two levels, the learner is ready to experience activities designed to motivate him/her to discover the need for "units"; i.e., the repeated use of the same quantity for purposes of comparing other quantities. Learners will find that, while they can do very simple comparisons with their senses alone, they eventually need more sophisticated means of measurement to supplement their senses. Thus, the learner will be led to choose arbitrary units of measurement and also appropriate measuring instruments.

Instructors should help the class become familiar with the unit concept. Have students measure objects with a variety of nonstandard units. A list of such units might include paper clips, pencils, books, sticks, straws, floor tiles, fingers and hands. Teachers should encourage students to pick their own units and discover advantages and disadvantages for their choices.

3.4.1 INSTRUMENT DEVELOPMENT

Experiences with a variety of measuring instruments (all nonstandard) will demonstrate that:

1. Objects can be measured in a variety of ways.
2. Efficiency in measuring comes from choosing an instrument appropriate to the object to be measured.
3. Some instruments provide a more accurate measure than others.
4. Units of various sizes are needed. (Paper clip units are satisfactory for measuring short distances, but a broom handle is better for measuring longer distances.).

3.5 MEASUREMENT. STANDARD UNITS

Understanding acquired at the premeasurement levels provides the foundation from which the learner will discover the need for standard units. Standardization is necessary to obtain consistent results and to communicate findings.

Before being introduced to standard units, students should be familiar with estimation and verification through the use of nonstandard units. Such experience helps them to think in terms of appropriately-sized units and instruments. It also helps them to gauge the reasonableness of their results.

3.5.1 INTRODUCTION OF METRIC SYSTEM

Having discovered the need for standard units, learners are ready for the metric system. Here the teacher can develop the logic of a measurement system which is based on ten and which corresponds with the base-ten numeration and monetary systems.

In the metric system, units of length are the basis from which units of mass, area and volume are derived. Therefore, units of length should be studied first, with various prefixes being introduced as they are needed.

The six common prefixes should also be studied in some detail for purposes of continuity and completeness and also for illustrating the base-ten nature of the metric system. The logic of the complete system must be developed in such a way that its decimal nature is clearly understood. Only the commonly-used prefixes, however, will be stressed for most measurement purposes.

3.5.2 METRIC CHART

The following metric chart is presented here to show the logic of the metric system, to introduce the metric prefixes and symbols and to emphasize the units that are commonly used.

The units in boldface type are those that students will learn early and use most often. Note by the boldface lettering that there are only four commonly-used units of length, two of volume and two of mass.

METRIC CHART

Base Unit	Added Prefix	Results	Written	Written	Commonly Used
	milli	millimetre	0.001 m	1 mm	Yes
	centi	centimetre	0.01 m	1 cm	Yes
	deci	decimetre	0.1 m	1 dm	No
Metre*		metre	m	m	Yes
	deka	dekametre	10 m	1 dam	No
	hecto	hectometre	100 m	1 hm	No
	Kilo	kilometre	1000 m	1 km	Yes
	milli	millilitre	0.001 *l*	1 m*l*	Yes
	centi	centilitre	0.01 *l*	1 c*l*	No
	deci	decilitre	0.1 *l*	1 d*l*	No
litre*		litre	*l*	*l*	Yes
	deka	dekalitre	10 *l*	1 da*l*	No
	hecto	hectolitre	100 *l*	1 h*l*	No
	kilo	kilolitre	1000 *l*	1 k*l*	No
	milli	milligram	0.001 g	1 mg	No
	centi	centigram	0.01 g	1 cg	No
	deci	decigram	0.1 g	1 dg	No
gram*		gram	g	g	Yes
	deka	dekagram	10 g	1 dag	No
	hecto	hectogram	100 g	1 hg	No
kilogram*	kilo	kilogram	1000 g	1 kg	Yes

*For definitions of the most important metric units--the metre, the litre, the gram and the kilogram—see the Glossary.

3.5.3 METRICS AND MONETARY

The chart below helps show the base-ten nature of the metric system. It also shows how metric prefixes are related to the appropriate values of the U. S. monetary system. Asterisks indicate those units most commonly used for measurement purposes. They also call attention to the fact that only a few units are used extensively.

THE COMMON METRIC UNITS

		(dollar)	metre	litre	gram
$\frac{1}{1000}$	milli	(mill)	*	*	
$\frac{1}{100}$	centi	(cent)	*		
$\frac{1}{10}$	deci	(dime)			
1			*	*	*
10	deka				
100	hecto				
1000	kilo		*		*

Prepared by Sharon Bernier, Associate Teacher, OMSI, 1975.

*Units most commonly used for measurement purposes.

3.5.4 METRICS AND BASE-TEN NUMERATION SYSTEM

The metric prefixes can also be related to the place values of our base-ten numeration system. The chart relates six common metric prefixes to the place values most commonly stressed as students learn the base-ten numeration system. Note that those place values which are less than one are expressed decimally.

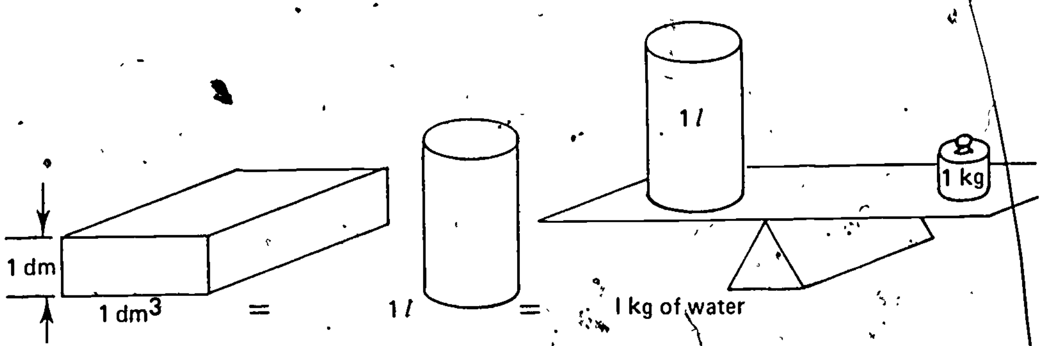
Numeration System (Place Values)		Metric System	
thousands	1000	kilo	1000
hundreds	100	hecto	100
tens	10	deka	10
ones	1	base	1
tenths	0.1	deci	0.1
hundredths	0.01	centi	0.01
thousandths	0.001	milli	0.001

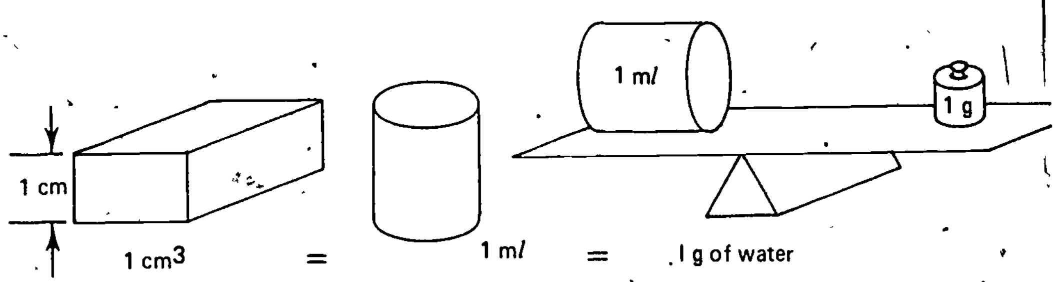
Decimal Nature

The previous chart implies that students need to be able to multiply and divide mentally by 10, 100 and 1000. This ability will make it easier for them to convert to smaller or larger metric units. Learners should be encouraged to use decimal notations (0.5 as one-half) rather than fractions. Decimals are easier to use, once the system is understood. They provide more convenience in computation whether it be by hand, calculator or computer.

Relationships

The original U. S. measurement system does not have a consistent relationship among length, volume and mass, but the metric system does! To see this, consider the containers below. They are all filled with distilled water at 4° C. The amount of water in each is the same.





3.5.5 RULES FOR SYMBOL USAGE

The metric symbols are used internationally and students should become familiar with them. Some rules for using the symbols of the International System of Units (SI)* follow.

1. Symbols of base units:

metre = m	litre = *l* (not l)
square metre = m^2	kilogram = kg
cubic metre = m^3	degree Celsius or $^{\circ}$C

2. Metric symbols should not be capitalized nor followed by a period unless their position in a sentence requires it. (Exceptions are units named in honor of a person, for instance, Celsius.)

3. There must be a space between the numerical value and the symbol of the unit.

4. The symbol for the plural is the same as that for the singular.

5. Units of area and volume should be written with an exponent, for example, m^2, km^2, m^3, cm^3. (The pharmaceutical "cc" is not used to indicate metric volume or capacity.)

6. An ordinary lower case "l" could be mistaken for the numeral 1; therefore, the symbol for litre should be written in italics or cursive script.

7. If a numerical value is less than one (1), a zero must precede the decimal point: 0.5 instead of .5.

8. It is necessary to use the degree symbol ($^{\circ}$) with Celsius ($^{\circ}$C) in order to distinguish it from coulomb (C), which is a unit for measuring electrical current.

9. The Celsius scale is preferred to the Kelvin scale as the international temperature scale, even though the Kelvin is the basic SI unit for absolute temperature. NOTE: the Celsius scale was previously called the "centigrade" scale.

3.5.6 SPELLING AND PRONUNCIATION

Considerable confusion exists regarding the spelling of some metric words. Sometimes a writer or agency will use one spelling, sometimes another. The Oregon Department of Education Metric Coordination Committee recommends using the spelling and pronunciation system first used by the General Conference of Weights and Measures (CGPM) on the International System of Units in its report. It was the 1960 conference which revised the older metric system to create the International System of Units. The CGPM used the t-e-r suffix for names of instruments; for example, odometer, micrometer, thermometer and meter. The suffix t-r-e is used for names of units; for instance, micrometre, litre and metre.

The CGPM plan for pronunciation also reflects internal consistency. The second syllable in names of instruments should be the accented one, as in odometer, micrometer and thermometer. The accented syllable in names of units should be the first one, as in centimetre, micrometre and kilometre. Thus, internal consistency becomes a factor in both spelling and pronunciation. This system has the added advantage of continuing the spelling and pronunciation of instruments to which Americans are already accustomed.

If this internal consistency in both spelling and pronunciation is maintained, particularly in regard to the words "kilometre" and "micrometre," the potential for confusing readers or listeners is reduced. Furthermore, this system is consistent with the spellings and pronunciations used in the 1960 International General Conference on Weights and Measurements report.

3.5.7 MASS vs WEIGHT

The confusing and inconsistent use of the terms "mass" and "weight" is a different type of matter (pun intended!). The terms "mass" and "weight" mean different things and should not be used as synonyms. "Mass" refers to the amount of matter in an object. Mass is measured in terms of grams in the metric system. "Weight" refers to the influence of gravity on an object. Gravity is measured in newtons. An astronaut will have the same mass on earth as on the moon, because the amount of matter will be the same in either case, but his/her weight will differ due to the different gravitational forces.

*These initials are based on the French spelling of the term, Le Systeme International d Unites.

The common use of the verb "weigh" contributes to confusion over these two terms. More accurate words would be "measure," "determine" or "find." This handbook deals with units of mass rather than weight; thus grams and kilograms are used.

3.5.8 AUTHORITATIVE REFERENCES

Every metric education leader should have a good reference for questions on spelling, symbols, definitions and style. The ODE Metric Coordination Committee recommends the following documents. Each is reliable, widely acceptable and low in cost.

The first is the *Metric Practice Guide*, E 380-76, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103. It costs $4.00. The second is the *NBS Special Publication 330, The International System of Units (SI)*, National Bureau of Standards (SD Catalog No. C 13.10:330/3), Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. It costs $1.00. A third reference is the *Metric Units of Measure and Style Guide*, USMA Metric Practice Committee, U.S. Metric Association, Inc., Boulder, Colorado 80302.

3.6 MEASUREMENT: APPLICATION

This handbook contains an "application" section for each kind of measurement, from length to temperature. Students should be encouraged to gain experiences in measuring everyday objects. While going through the "application" exercises with the class, the teacher should remember the following principles:

1. All measurement learning should originate from "hands-on" activities and experiences.
2. The importance of estimating measurements and then verifying that estimate should be stressed.
3. Many activities should involve direct measurement with metrically scaled instruments.
4. The actual size units should be used, not the scaled-down versions found in some commercial metric materials. This will help students acquire a correct impression of unit size.

3.6.1 MAKING APPROPRIATE CHOICES

As students progress, teachers should continue to place emphasis on choosing appropriate units of measurement (e.g., a unit of length to measure length).

In addition, students should become sensitive to the size of the units they use. Choosing small units for small distances and large units for large distances is more convenient and results in more accurate measurements. Students should also learn to choose instruments appropriate to the attribute to be measured, e.g., the balance to measure mass.

3.6.2 APPROXIMATE NATURE OF MEASUREMENTS

Learners have often been given the idea that measurement is an exact science. Textbook measurements like 0.37 sometimes create the impression that this measurement is exact, but 0.37 probably means the quantity is somewhere between 0.365 and 0.375. Every now and again learners should be reminded of the approximate nature of measurement. (In the interest of brevity, this handbook does not deal with precision, significant digits, greatest possible error and relative error.)

3.6.3 CONVERSIONS, A NO-NO!

During the teaching of basic metric measurement concepts and skills, it is not wise to teach conversion between systems. In fact, using conversions and teaching standardized units before the learner's discovery of a need for standardizing may be the two most frequent errors in the teaching of measurement! If conversions become necessary, conversion tables, charts or calculators should be used rather than memorized conversion factors.

Some referents are useful, however, during the early stages of the changeover.

A metre is a little longer than a yard.

A litre is a little larger than a quart.

A kilogram is a little more than two pounds.

An inch is about 2.5 centimetres.

Teachers might introduce common metric measurements by relating them to objects with which the students are familiar, for instance:

One white Cuisenaire rod is a cubic centimetre.

1500 m is approximately one mile.

One plump raisin has a mass of about one g.

One nickel has a mass of about five g.

The temperature at which water freezes is 0° C.

The temperature at which water boils is 100° C.

37° C is normal body temperature.

One L (about one quart) of water has a mass of one kg.

A jumbo paper clip is about five cm by one cm. It has a wire diameter of one mm and a mass of less than two g.

Think Metric

Students need to THINK METRIC. They should not be dependent on a translated measurement system. Thinking metric means visualizing relative size in metric units. Students should be encouraged to use the more common metric units even when doing conversions within the metric system. Conversion from one less-used unit to another (such as km to dm) and the addition of unlike units are generally impractical exercises. The emphasis should be directed toward understanding the relationships among metric units, which are all based on powers of ten.

4. MEASUREMENT ACTIVITIES

DIAGNOSTIC AND/OR LEARNING EXERCISES

This section of *MEASUREMENT. . .with Metric* presents a series of premeasurement and measurement activities. The suggested activities at each of the learning levels may be used as diagnostic or learning exercises. Teachers are encouraged to tailor each activity to meet their students' needs.

A diagnostic approach allows the teacher to prescribe the most appropriate learning activities as the student progresses from concept to concept on a given learning level and/or to advance from learning level to learning level within a given measurement concept. (See chart on page 8.) In some instances an activity may be designed to help a child achieve a new learning level and it may involve two or more measurement concepts. Additional learning activities are exhibited in the AIT television series and in the teacher guide which accompanies it. (See pages 36-37.)

METRIC: A RESPONSE

It should also be noted that this handbook does not spell out specific strategies for introducing the metric system itself, except to indicate that this may occur at the learning level referred to as "standard unit." This placement suggests that introducing the metric system occurs as a *response to a discovered need for a standardized unit*. This strategy will also be observed in the television series *"MeasureMetric."*

Teachers generally recommend that only those parts of the metric system be introduced which are needed by the students at that point in their development. These parts are referred to in this handbook as "standard units." Students can add units to their collection as they need them.

MEASUREMENT. . .with Metric stresses the commonly used prefixes. The entire set of prefixes will be presented, however, as the base ten nature of the metric system is developed.

Although the recommended approach to the teaching of measurement is the "hands-on" one, teachers will still need to make some decisions regarding the memorization (base units, system of prefixes, symbols), drill and practice which they require of students. In general, the teaching of the metric system as a part of the more basic area of the teaching of measurement, offers many options to teachers in choosing from their personal collection of strategies, materials and methods of evaluation.

The following activities are presented in the form of instructions to teachers. The exercises are simple but demonstrate important measurement concepts. Some of them include an "extension" activity which represents a step forward from the basic activity. It may be appropriate only for some students.

4.1 CONCEPT I: LENGTH

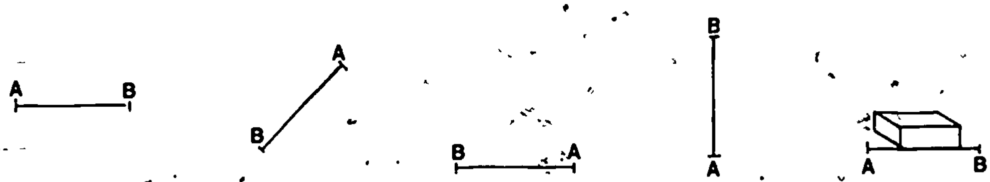
4.1.1 LENGTH: CONSERVATION

4.1.1.1 See "The Paper Strip Activity" in "Teacher Workshops" pages 45-47, for a series of activities dealing with the concept of length. The series involves all five learning levels.

4.1.1.2 Provide two strips (such as paper or string) which are about the same length. Ask the learner if their lengths are the same. Trim the strips, if necessary. Perform several experiments to see how bending, curving and folding influence the length. Then have students cut one strip into three pieces to determine how cutting influences the length.

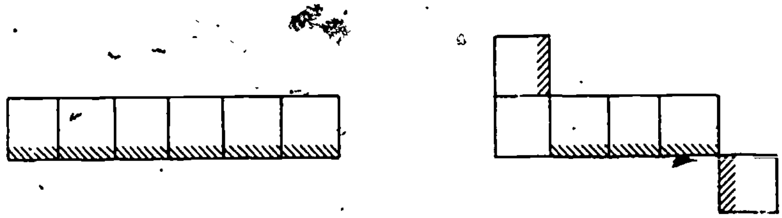
4.1.1.3 Provide two sticks of about the same length. Have students place one on top of the other, shift one a little to one side and compare the lengths. Have them place one stick farther from the viewer than the other and compare the lengths. Then have them place the two sticks in several different positions to determine if this changes their length.

4.1.1.4 Look at the illustration and determine which of two straight line segments represents a greater distance; for instance, is the distance between A and B the same if the line is slanted? If one line is vertical and one horizontal? If an object is placed between A and B?



4.1.1.5 Have the learner form two identical rows of 10-15 precut squares. The learner can see that the number of squares in each row is equal to the number in the other through a one-to-one correspondence. Have students place the squares in one row further apart. Which row has more squares? Place the squares from one row in a pile and question the learner about the number of squares in the pile compared to the number of squares in the remaining row.

4.1.1.6 Have students color one edge of each square with short, diagonal lines. Then have them arrange the squares so that the colored margins form a continuous straight line. Rearrange the squares so that the line forms a zig-zag pattern. Ask students if the total length of the colored line changed when the squares were rearranged. Explore various patterns.



4.1.1.7 Have learners demonstrate on a geoboard a number of different shapes which all have the same perimeter. Strips of paper ribbon or string should be substituted for the rubber bands usually used in order to maintain the constancy of the perimeter.

4.1.1.8 Have teams build towers out of the same number of equally sized blocks. Have different teams build their towers by starting from various levels within the room, for example, from the floor, a chair, or a stairstep. Discuss and compare the heights of the towers.

4.1.2 LENGTH: COMPARISON

4.1.2.1 Arrange for the class to view the first program of the metric television series *MeasureMetric** and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide** and/or the activities listed below.

4.1.2.2 Have students list some common properties other than size—color, shape, texture, odor and taste, for example—that can be used to compare objects. Compare them by observing each property.

**MeasureMetric*, Agency for Instructional Television, Bloomington, Indiana, 1976.

4.1.2.3 Have students make two belts from ribbons, string or unmarked tape, and compare the length of the two belts to their heights. Then have them use ribbon, string or unmarked tape, and compare the distance around their heads to that of their waists, their heights, and their feet. Compare the distance around their wrists to that of their heads, waists and ankles. What relationships can be found? Are they the same for all students?

4.1.2.4 Measure the height of each student. Then cut individual strips of adding machine paper equal to each student's height. Tape the strips to a wall, starting each from the floor, thus forming a graph. Have the class rearrange the order of the strips from tallest to shortest. Similar graphing may be done with various body measures.

4.1.2.5 Have the class keep a graph to show the increasing heights of plants as they grow. Use paper strips or paper straws, cut to each plant's height, as vertical bars.

4.1.2.6 Direct the students to prepare a graph showing how tall everyone in their families is. Have them arrange the graph so that their family is ordered, tallest to shortest. They might even include pets.

4.1.2.7 Have students measure animals such as hamsters, gerbils, dogs and cats to learn if a "measuring string" or a "measuring stick" is better to measure height, length, tail and tummy girth. Which animal is taller? longer? fatter? Measure each animal's cage. Is there room enough for it to stand up? lie down? stretch out? hide in a corner?

4.1.2.8 Have students use string to measure each other's shadows and heights. Have them compare the length of their shadow to their height. Have students try this at different times of the day. Have teams of three students measure each other's height, and arrange the results in order from tallest to shortest. Now have them measure their shadows. Arrange shadow lengths from longest to shortest. Extension. Have students graph their findings according to a scale of one to two or one to four.

4.1.2.9 Lead the class in comparing two objects directly by placing them next to each other. Consider heights, widths and lengths. Then have students compare three objects by placing only two at a time next to each other (transitivity). Compare two large objects which cannot be placed next to each other (e.g., door and window) by comparing each against a third smaller object, such as a sheet of paper, unsharpened pencil, chalkboard eraser, etc. This exercise introduces the unit concept.

4.1.3 LENGTH: UNIT CONCEPT

4.1.3.1 Arrange for the class to view program 2 of *MeasureMetric* and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide** and/or the activities below.

4.1.3.2 Have learners measure various distances by making lines (trains) of sticks, straws, Cuisenaire rods, paper clips, lima beans, macaroni and their own foot or hand patterns. For instance, have students place seven straws end to end. Extension: Measure some distances by using only one object counted repeatedly, for instance, one straw moved and counted seven times.

4.1.3.3 By stepping off, heel to toe to heel, have the students determine the "foot" count for various objects or shadows. Have them cut out a paper "personal foot" pattern and use it for measuring a variety of objects. They may use a hand or a finger, too. Ask several students or groups to

**MeasureMetric Teacher's Guide*, Agency for Instructional Television, Bloomington, Indiana, 1976.

measure the same object and compare their results. Have the class choose one person's hand, finger or foot as a common unit, then have several persons or groups measure the same object and compare their results.

4.1.3.4 Have each learner use his/her "pace" or length of step to measure a variety of objects and shadows. Encourage comparison of results.

4.1.3.5 Have students cut a string to match their heights and ask them to find objects half as tall or twice as tall as themselves. Direct them to fold the string in half and use this new length as a unit for measuring other objects.

4.1.3.6 Have the class estimate the length of the chalkboard in terms of pencils, sticks, paper clips, books, paper strips, sheets of paper, linoleum tiles or erasers and then measure and verify the estimations. Have them tell a friend in face to face conversation, by telephone or by letter, about the length of the chalkboard.

4.1.3.7 Have learners choose their own measuring units and make measuring "sticks" and measuring "tapes." The sticks may be made from unmarked molding (scraps from the local lumber yard). Tapes may be made from adding machine tape (perhaps reinforced with a strip of masking tape) or two strips of masking tape put together. Learners may wish to name units or instruments in their honor.

Students should use these instruments in a variety of measurement activities. Have them compare their results with those of other students. Extension. Have learners use their chosen units to measure some very small objects and some large objects. Discuss the advantages inherent in using different units in each case so that students discover the need for more than one unit.

4.1.3.8 Make chains of various lengths from paper clips, and use each chain as a unit. Have students use one of their units to measure a pre-selected distance (known only by the teacher to be about 10 paper clips long). Then have them measure the pre-selected distance in terms of the following chain units: a chain of 2, 5, 8, 10 and 20 paper clips. Measure objects of various sizes with different chains. Which size unit results in a measurement system which is most compatible with the base ten numeration system? Extension: Have learners develop a base ten measuring system with multiples and submultiples according to learner discovered needs for convenience and accuracy. Basic units may be straws as well as paper clips. Then submultiples can be made by cutting, and multiples can be made by threading straws on a string.

4.1.3.9 Use a paper clip for a unit called "clip" and a chain of ten paper clips for a unit called "chain." Have the class measure a variety of objects—a desk, hand, foot, book, box, sheet of paper—to the nearest "clip." Then have them measure other objects—doors, windows, rooms—to the nearest "chain." How can better accuracy be obtained? Devise and try out a plan. Encourage estimation as a part of "chain" and "clip" measurements.

4.1.3.10 Have students measure large objects in terms of a small basic unit. Help them discover the need for a larger unit as a multiple of the basic one. Then have them measure between limits. A sheet of paper, for example, might be between two and three pencils in length. Help students see the need to subdivide the basic unit when smaller units will make accurate measurement easier.

4.1.4 LENGTH: STANDARD UNIT

4.1.4.1 Arrange for the class to view program 3 of *MeasureMetric* and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide** and/or the activities below.

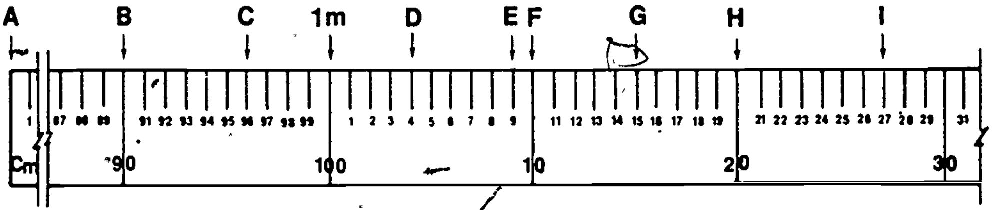
**MeasureMetric*. Agency for Instructional Television, Bloomington, Indiana, 1976.

4.1.4.2 Ask students to use a tape measure and ruler to find some dimension of their bodies that closely approximates a metre, decimetre, centimetre and millimetre. Record the findings. These results will be useful in estimating distances.

4.1.4.3 Provide paper or plastic straws. These can be cut into one cm, five cm or any other lengths. A different color for each length is helpful. Have the class measure a variety of objects in terms of the straws. Students in the primary grades enjoy straw "rulers" and they provide a neat transition from nonstandard units to standard units. So do "jumbo" or five cm paper clips.

4.1.4.4 Happiness Contest: Form groups or teams of two to four people. Have students measure the smiles of their group to the nearest millimetre. Who has the widest smile? Which group has the widest smile, collectively? Extension: Graph the results.

4.1.4.5 Place two one-metre sticks or two actual size drawings end to end, as in the diagram. Point A is at zero. Other labeled points are located as shown. Have students write the *decimal form* of each of the following lengths *in metres:* AB, AC, AD, AE, AF, AG, AH, AI. (Try FH, GH, HI.)



(This illustration is not to scale, but models for use in the classroom should be actual size.)

Extension: Some teachers have found that metre sticks in which the numerals on the stick count centimetres are excellent physical models of number lines and are useful for teaching number concepts in primary grades. Older students may gain practice with "thousandths" by finding points along the millimetre marks. Millimetre marks are not included in the illustration above, but do appear on many metre sticks.

4.1.4.6 Renaming metric measurements: This activity provides an opportunity for some "guided discovery" exercises utilizing decimal-fraction notation. Such exercises should be based on previously learned mental short-cut procedures for multiplying or dividing decimals by 10, 100 and 1000. Some well-selected exercises may lead the learner to two generalizations: (1) to change a metric measurement to smaller units, multiply by 10, 100, or 1000 and (2) to change a metric measurement to larger units, divide by 10, 100, or 1000. After students discover this generalization, design some follow-up exercises which use the decimal nature of the metric prefixes and which guide learners to the following conclusion: To rename metric measurements, write the numeral so that the decimal point is just to the right of the digit in the column which names the measurement unit to be used. Observe the first of the four examples below. In 3 579.1 cm the digit 9 names the number of centimetres. In 35.791 m the digit 5 names the number of metres. In 3 579.1 cm the digit 5 also names the number of metres.

Examples:

dam	m	dm	cm	mm	
3	5.	7	9.	1	cm = 35.791 m

m	dam	cm	mm	
2.	4	6	8	m = 2 468 mm

km	hm	dam	m	dm	cm	mm	
3	4	5	6	7	8	9	mm = 345 678.9 cm = 3 456.789 m = 3.456 789 km

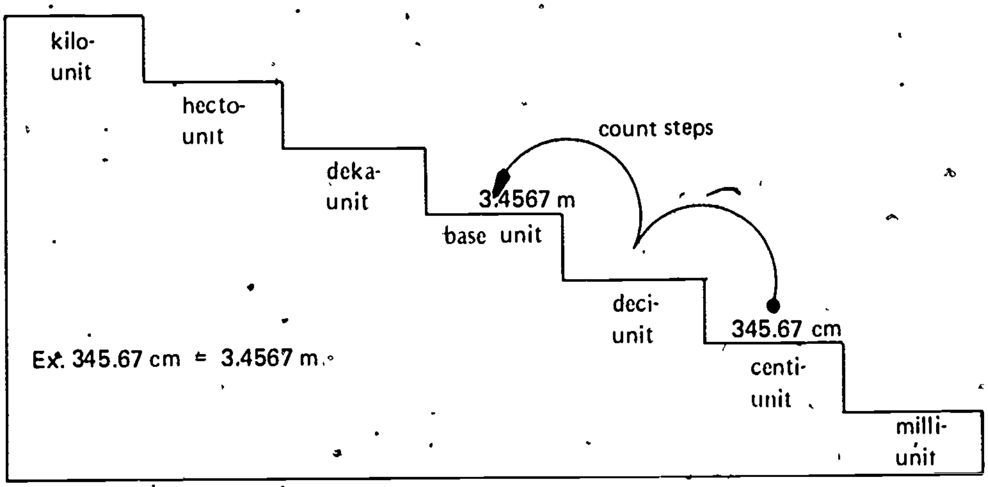
Note that numerals are arranged in blocks of three digits, without commas, and that a space occurs between the last digit and the symbol for the unit.

4.1.4.7 Teachers have used several forms of "expanded notation" to reinforce the place-value concept of decimal numeration. Use an analogous procedure to bring out the decimal feature of the metric system.

Examples:

356 = 300 + 50 + 6
356 cm = 3 m + 5 dm + 6 cm
25.73 = 20 + 5 + .7 + .03
25.73 m = 2 dam + 5 m + 7 dm + 3 cm

4.1.4.8 Mr. Boyd Henry illustrates the idea of decimal point placement with a simple, mechanical procedure for changing from one metric unit to another. He uses a staircase chart.* Have students locate the original unit on one of the steps, count the steps to the new unit and move the decimal point that many steps in the same direction, as illustrated below. The chart and the procedure will work in the same manner for units of length, volume or mass.



4.1.4.9 Have the learners make their own metre or centimetre sticks or tapes by using unmarked molding, adding machine tape or masking tape. They should use their own instruments in a variety of measurement activities. Have the learners compare their results to those obtained by others. Include some activities which create a need for multiples and sub-divisions of basic units.

4.4.10 Conduct a unit recognition test. Give the student five lengths of paper, varying from each other by about 15 percent. Make one of the lengths one m. Have the student select the one metre length. Use the same procedure for the centimetre length.

4.1.5 LENGTH: APPLICATION

4.1.5.1 Arrange for the class to view program 4 of *MeasureMetric* and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide* and/or the activities below.

4.1.5.2 Have students estimate and draw the following straight line segments: 1 cm, 10 cm, 10 mm, 100 mm, 0.01 m, 0.1 m. Then have them use a ruler and draw the actual length. Outdoor activities may involve the metre and kilometre. For an alternative activity give students line segments of various lengths and have them estimate and then verify the lengths.

*Boyd Henry, *Teaching the Metric System,* (Chicago: Weber Costello, 1974), p. 16.

4.1.5.3 Have the student measure each of the following: his/her height, length of smile, cubit, arm span, length and width of forefinger, length of shoe, length of stride and height. Then ask him/her to measure the length and width of a dollar bill, length and width of a door, diameter and thickness of a nickel, length and width of a jumbo paper clip and the diameter of the wire. Measure many *common* objects. Extension: After some experiences measuring objects, learners should be encouraged to estimate lengths. Do not penalize poor estimates as this discourages estimating. The procedure should be to estimate, record and then verify with a measurement. Estimating can be made easier by using the results of measuring such things as those listed above. For example, have students mark off a 10 m distance and count the strides in it. Repeat several times and determine the average.

4.1.5.4 Instruct students to measure the "bounce height" of several different balls when dropped from several different heights and record the results. Extension: Graph the results to scale, e.g., 1 mm = 1 cm.

4.1.5.5 Make a deck of cards for playing "twenty-one." Each card should have a line segment on its face. The segments are one, two, three, four or five centimetres in length. The three cm length should be included more than the others, and the one cm and five cm lengths should occur least frequently. Use rules as in the card game called "twenty-one." Have each player decide lengths through estimating rather than measuring. Players win when they get a sum closer to 21 cm than the dealer does, without going over. An actual measurement will verify winners. For use at the primary level, ten may be chosen rather than 21, although any number may be used.

4.1.5.6 Hold a prediction contest. Participants may practice and measure the events until they feel confident. Then each participant predicts what he or she will do in each event, records the predictions, performs each event, measures and records. Determine the total numerical difference between the prediction and the actual measurement. This activity may be conducted as a competition between individuals or teams. (It's more fun for teams!) This entire activity may also be done with nonstandard units.

Four possible events are:

(a) Standing long step. Participant takes one giant step from a starting line and measures from line to heel with a centimetre tape measure;

(b) Cotton ball put. Participant "puts" a cotton ball from a starting line and measures with a centimetre tape from line to where the ball stops;

(c) Straw javeline throw. Participant hurls a straw javelin from the starting line and uses a metre stick to measure in centimetres from the line to the leading point of the javelin;

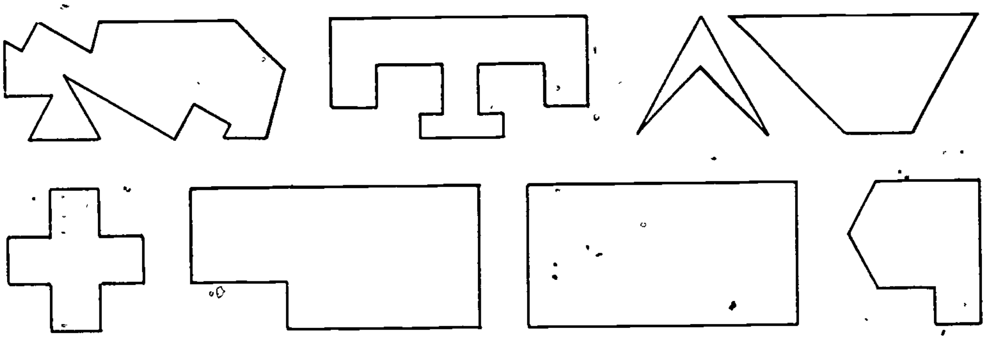
(d) Paper plate discus throw. Participant hurls the discus, then uses a trundle wheel to measure in metres from the line to the leading edge of the discus.

4.1.5.7 Have students measure the height of objects and the length of their shadows to discover a relationship. Then determine the height of other objects by measuring their shadows. Extension: Graph the results.

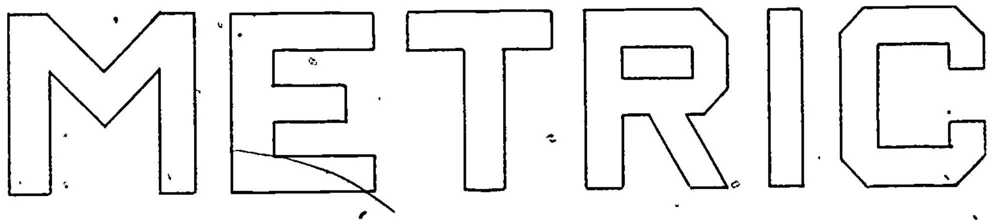
4.1.5.8 Hold a "Mystery Measurement" contest. Have the class measure assorted objects in the room—boxes, books, games, cards, furniture. Include some standard-sized items. Record the dimensions. (Areas or volume may be used, depending on the learning level of the student(s).) Write sets of "mystery dimensions" on the chalkboard. Ask students to use their measuring instruments to measure objects until they can identify the mystery objects. Extension: Students may play a mystery contest by contributing their own mystery dimensions.

4.1.5.9 Help students determine perimeters. Prepare a worksheet by drawing a number of geometrical shapes. *Use actual metric lengths.* Tell students to use a metric ruler and find the perimeter or distance around each figure. Draw a variety of shapes, making the degree of complication appropriate to the learner. Here are a few examples:

Group 1:



Group 2: Find the total perimeter of the letters.



4.1.5.10 Help students find a way to measure the distance a nut travels up or down a bolt during one complete turn. Work with students in measuring the thickness of one sheet of paper. One way of doing this is to measure the thickness of a stack of 100 sheets, then compute the thickness of one sheet.

4.1.5.11 Have students construct as many rectangles as possible, such that the perimeter of each is 20 cm and the widths are a whole number (i.e., 1, 2, 3,. . .) of centimetres. This may be done on geoboards, metric graph paper,* or plain paper. Extension: Have students create a variety of closed, two-dimensional figures such that each side is a whole number of centimetres long, and each perimeter is a given amount. (See cm^2 paper at back of book.)

4.1.5.12 Are model cars really models? Find a foreign car, if possible, its brochure and a model of it. Have students use a metric ruler to measure the model's wheel base, front track, rear track, length, width and height. Then help them determine the scale and calculate the dimensions of the real car. Compare the results to the specifications given in the new car brochure. Comparisons can bring out some interesting results!

4.1.5.13 Have the class measure some outdoor physical objects. Make scale drawings and paint the pictures. (The scale could be one m to one dm or one m to one cm.)

4.2 CONCEPT II: MASS

4.2.1 MASS: CONSERVATION

4.2.1.1 Place a lump of modeling clay in one pan of an equal arm balance. (This may be a homemade balance like the one described in 4.2.2.5.) Have students add objects to the other pan until the

*Ask science teachers where they get metric (cm^2) graph paper or make a copy of the centimetre square grid at end of book.

two pans balance. Now have them roll the modeling clay into a long, skinny "snake." Does it still balance? Does it balance if the "snake" is broken into little pieces? Does it still balance if the clay is molded into the shape of some animal? Have the class compare a ball of clay with the clay squashed into a "pancake."

4.2.1.2 Using an equal arm balance, have the student compare the mass of an arbitrarily chosen unit against a small bag of "goodies," for example, corn chips or potato chips. After the two objects have balanced, remove the bag of "goodies" from the balance and crush the contents. (Careful with the bag!) Have the student return the bag of "goodies" to the balance. Does it balance now? What does this show?

4.2.1.3 Balance a quantity of unpopped popcorn with an equal mass of an arbitrarily chosen amount of mass, perhaps of modeling clay. Instruct students to pop the corn and return it including the unpopped kernels, to the balance. Does it balance now?

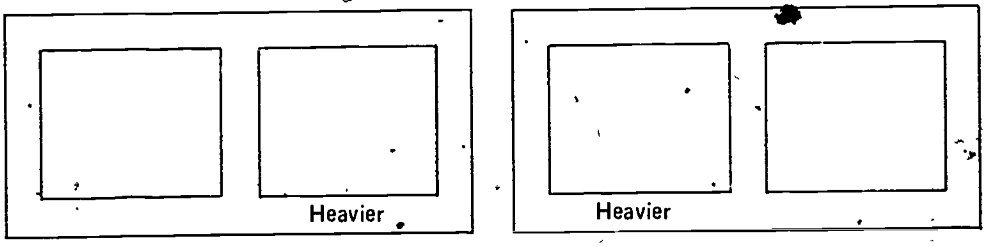
4.2.1.4 Using ice cubes placed in a container, have a student balance them with an equal mass, perhaps modeling clay. Let the ice cubes melt. Return the container and its contents (now water!) to the balance. Does it balance now?

4.2.1.5 Have students balance a pie or cake with an equal mass. Then cut the pie or cake into a number of servings, being careful that crumbs are not removed with the knife. Does the "goodie" still balance with the same amount of mass? What does this show?

4.2.2 MASS: COMPARISON

4.2.2.1 Make a see-saw with a plank and a brick or building tile. (The world's first equal arm balance?) Find out which of two children has a greater mass. Compare different objects.

4.2.2.2 Cut the tops from several milk cartons. Provide supplies of sand, rice, beans, marbles, popcorn or other substances. Have the students put amounts of the granular substance in two milk cartons. Mark off two equal rectangles on a larger rectangular card. Label one of the pair with the word "heavier." Then place the cartons on the card to show the correct mass relationship.

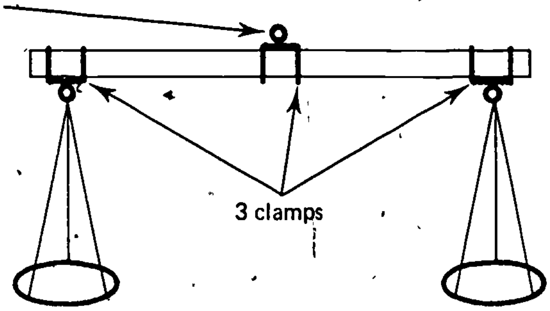


4.2.2.3 Compare pairs of objects to determine which has greater mass. Have students lift them to compare the mass of each and then verify their findings with an equal arm balance. Some suggested pairs are: ten pennies and ten dimes, 200 kernels of unpopped and 200 kernels of popped popcorn, a bottle of glue and the same sized bottle of water, a chunk of metal and a bag of feathers, chunks of different metals like lead and aluminum, an apple and an orange, a banana and a tangarine, five potatoes and five onions, a baseball and a football, a softball and a basketball.

4.2.2.4 Provide each team of two students with a variety of small objects. Have the students lift them to compare their masses. Find objects having about the same mass. Ask students to arrange them in order from lightest to heaviest. Verify the order by using a balance. Extension: What is the minimum number of times a balance must be used to order three objects? Four objects? Five objects?

4.2.2.5 Help students make an equal arm balance. Use one metre stick (or piece of molding, stick or ruler about 40 cm or more in length); three clamps like the ones on clip boards; two containers, for example, styrofoam cups, cottage cheese cartons, refrigerator plastic containers or cutoff milk cartons; some string and some masking tape. Have the student place one clamp, handle up, at the center of the stick and one clamp near each end of the stick, handles down as illustrated. Instruct the student to suspend the stick by putting a pencil or dowel through the handle of the center clamp and then fasten the pencil to a table top or a box so that it projects beyond the edge. Cut the string into six 25 cm lengths and tape three strings to each container. Tape the three strings from each container to the handles of the two end clamps. Have students adjust the clamps back and forth until the stick is level.

Estimate the mass of many different objects and then use your balance to compare their masses.



4.2.3 MASS: UNIT CONCEPT

4.2.3.1 Arrange for the class to view program 11 of *MeasureMetric* and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide* and/or the activities below.

4.2.3.2 Collect several sizes of iron washers. A large number of each of the sizes is needed. Some should be very small, others quite large. Have the class use a balance to measure the mass of various small objects in terms of combinations of washers. Students may have more fun by making estimations first. Record and compare results.

4.2.3.3 Using the metre stick balance constructed in 4.2.2.5, have students compare the mass of small objects to some arbitrarily chosen unit of mass. They may experiment by selecting "units" from collections of different sized stones. Different students should compare their findings for the mass of the same object. Have them write to a friend about the mass of the objects measured to see if communication can occur when such units are used.

4.2.3.4 Using the balance learners constructed in 4.2.2.5, have them choose a unit from collections of objects such as marbles, paper clips, iron washers, lima beans, thumb tacks, nails, unused pieces of chalk or chalkboard erasers. Then have them measure the mass of a variety of small objects in terms of the unit they have chosen. Have students compare results. Is communication easier now than when they used stones for units, as in 4.2.3.3? Discuss. Extension: Choose from the above materials an amount representing one unit. Use baggies of material to make multiples of that unit, in particular, two units, four units and eight units. What amounts of mass could be balanced with combinations of these units?

4.2.3.5 Using a balance, have students determine the mass of a rock in terms of the mass of an arbitrarily chosen unit. Have them compare a unit mass of clay, for instance, with the mass of the rock.

If the rock has a greater mass, more units will be needed. Have students make another unit mass of clay with a mass equal to the first unit. Compare them on the balance to verify that they are equal. Then place the two units in one container and the rock in the other container to see if the mass of the rock is the same as two units. Make more units, if needed.

If the rock is less than one unit, or on further measurement is somewhere between whole units, subunits are needed. Keep at least one whole unit intact. Have students subdivide another unit into halves, comparing the two on the balance. If further subdividing is needed, prepare quarter units in the same manner. Continue subdividing until the mass of the rock can be measured with a combination of the units created.

4.2.3.6 Have students make a balance. Start by drilling a hole in the exact center of a metre stick. Put a hook through the hole. Cut off two half gallon milk cartons at a height of 103 mm so that each carton has a capacity of about one litre. Attach strings to the upper corners. Tape these to the ends of the metre stick, adjusting them so that the stick will be level when suspended.

Have teams or "tribes" of students barter for goods. Each tribe should choose a mass unit, for example, a marble, an eraser, a small book, selected stones, a box of thumb tacks, a pair of scissors, a block of wood, a measured volume of water or sand. Each team will need to have a number of their own unit available.

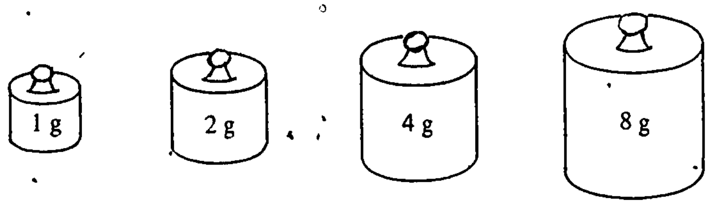
For this activity, make the following units equal in value: two units or rice = three units of beans = four units of potatoes = one unit of yellow apples = one and one-half units of red apples = two and one-half units of bananas = three and one-half units of oranges = four and one-half units of grapefruit. (As an alternative, rocks painted different colors for each commodity may represent units.) Give each tribe only one commodity.

Attempt "world trade" by using the equal combinations identified above. Since the tribes do not trust each other, have them measure each transaction in terms of their own units and their own balance. When the tribes discover that "world trade" is seriously hampered, ask a "council of the tribes" to choose an "international" unit. Provide new supplies to all tribes so that they can measure with the "international" unit. After some transactions with this "international" unit, have the tribes discuss its advantages.

4.2.4 MASS: STANDARD UNIT

4.2.4.1 Arrange for the class to view program 12 of *MeasureMetric* and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide* and/or the activities below.

4.2.4.2 A set of mass pieces contains the following units:



Show how the above mass pieces can be used to represent masses of one g, two g, three g . . . 15 g. Have students find combinations of the pieces for each of the following: one g, two g, three g, four g . . . 15 g.

4.2.4.3 Hold a scavenger hunt. Have students find objects with masses equal to those specified in a given list. Prepare the list in advance by measuring, with a balance, the mass of a variety of objects common to learners. Following are some examples:

kg (the teacher)
kg (the unabridged dictionary)
kg (a chair)
kg (a concrete block)
kg (a bottle with about one *l* of water)
g (a math book)
g (a chalkboard eraser)
g (a spelling book)
g (the apple on the teacher's desk)
g (a metric ruler)
g (an unsharpened pencil)

4.2.4.4 The mass, in grams, of water in a container may be determined by using a balance. Have students measure the mass of the container when empty and when filled, then subtract to determine the mass of the water alone. Have them use this procedure with measured volumes of water: 25 m*l*, 1 *l*, 3 *l*, 250 m*l*, 1500 m*l*, 600 m*l*, 40 cm^3, and 2000 cm^3. Such experiences are intended to help students discover a relationship between volume and mass.

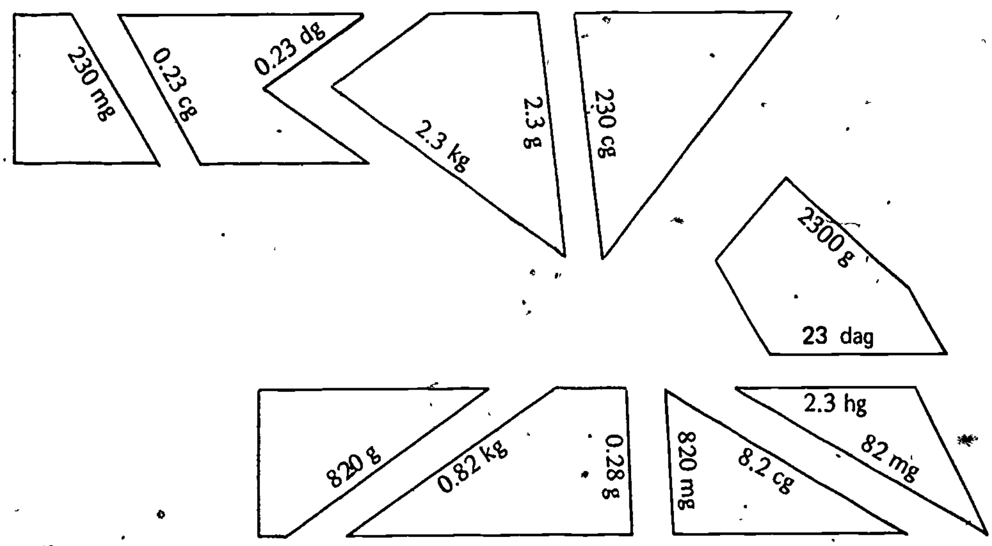
An alternate approach to this activity would have the student determining the volume of the water from a given mass of water. Again, encourage students to look for a relationship.

4.2.4.5 Have students estimate and record the mass, in grams, of one litre of water. Then have them measure 100 m*l* of water into a graduated beaker. Use the balance to determine the mass, in grams, of the water. Use the results to compute the mass of 1000 m*l*, or 1 *l*, of water. Emphasize the importance of this relationship in the metric system.

4.2.4.6 Ask students to find "story problems" involving weight in their math books. Ask them to restate the problems, using metric units of mass, so that the new problems make sense.

4.2.4.7 Give students a unit recognition test. Place five objects, the masses varying from each other by about 15 percent, in front of the students. One object should have a mass of one kg. Have the students select the mass of one kg by lifting rather then using a balance.

4.2.4.8 Ask students to arrange cutouts of the drawings below so that they form a big "M." The edges that go together are marked with equal measurements of mass.



4.2.5 MASS: APPLICATION

4.2.5.1 Have students use a balance and find the mass of many objects. Try books, a bunch of potatoes, canned food, stones, pieces of wood, pieces of metal, erasers, shoes, themselves, one litre of materials like beans, rice, sand, water or marbles. After some measuring experiences, learners should be encouraged to estimate masses. Estimates should be verified with measurements.

Extension: Hold an estimation contest. Have teams estimate the mass of various objects and then record the estimates. Verify them by using a balance. Devise a scoring system like "estimates within one kg are worth one team point. Those within 500 g are worth two team points. Those within 250 g are worth three team points and so on." Call particular attention to the mass of various quantities of water, for instance, 1.0 *l* and 0.5 *l*.

4.2.5.2 Divide the class into teams. Have each team choose items whose masses it will determine. Then have the teams record the names of the objects and their estimate of each object's mass. Now have each team use a balance to determine the mass of each object. Teams may wish to measure the opposing team's set of objects. The difference between the actual and the estimated mass is calculated for each object. The team whose estimate was closest earns five points, next closest earns four points, and so on. Highest total of team points wins. (Winners do not have to help put all the equipment away!)

4.2.5.3 Hold a prediction contest. Put some popped popcorn in container A, marbles in container B, small stones in container C, beans in container D and similarly sized substances in other containers. Have a student reach into a container with one hand to grab as much of that substance as possible. Measure the mass in grams with a balance. After sufficient practice, have each participant predict his or her "one-hand-grab" for each container. Record the predictions. Measure all performances with a balance and record results. Calculate each person's score as the difference between the predicted total and the actual total. Individuals or teams may compete, although a team approach will be more fun. Note that this activity may be tried at an earlier learning level if nonstandard units are used.

4.2.5.4 Collect unopened containers of a variety of dry cereals. Be sure to cover the part of the label which lists the net contents. Collect a like set of empty containers. Have learners calculate the mass of the net contents by using a balance to measure the mass of each container. Have students do the same with laundry detergents, canned food, boxed candy and other substances.

4.2.5.5 Provide a balance with one-gram mass pieces, a small postal or diet scale graduated in grams and several envelopes stuffed with different amounts of paper. Have the student measure the mass of each envelope, determine the number of postage stamps needed, calculate the mailing cost and record the results on a worksheet for determining mailing costs. The teacher will need to supply students with a chart showing mailing rates based on mass in grams.

4.2.5.6 Have students determine the grams of mass in an apple and record. Then have them take a bite, determine the mass and record it. Students should repeat bites until they have finished the apple. Are the bites all the same size? What was the largest? smallest? average? How much of the apple was eaten?

4.2.5.7 Provide one large bag of unpopped popcorn and one small bag containing 20 kernels of unpopped popcorn. Have students estimate the number of kernels in the large bag. Have them measure the mass of both bags of popcorn and figure out the number of kernels in the large bag without having counted them.

4.2.5.8 Make billfold-sized cards with a centimetre scale along the margin. On one side of the card print some approximate comparisons between customary and metric units. (You may wish to include both length and mass.) On the other side print some approximate metric measurements of several carefully selected common objects. If the students plan the card and choose the items,

the project will be more meaningful to them. Have the cards plasticized or laminated. The students may use these cards themselves or give them as gifts to parents or to visitors. The cards could also be sold as a money-making project.

4.2.5.9 Help students discover a relationship between mass and volume. Supply two solid cubes of the same material, perhaps one whose edges are one cm and the other whose edges are three cm. Have students measure the edge of each cube to the nearest centimetre and record. Then have them compute the numerical ratio of the lengths of the edges of the two cubes. Have them use a balance to measure the mass of the smaller cube to the nearest gram and record. Instruct them to lift both cubes and estimate the mass of the larger cube in grams and record. Then have the students use the balance to measure the mass of the larger cube to the nearest gram and record. Tell them to compare this result with their estimate. Finally, have them compute the numerical ratio of the masses of the two cubes and record. Discuss their findings.

4.3 CONCEPT III: AREA

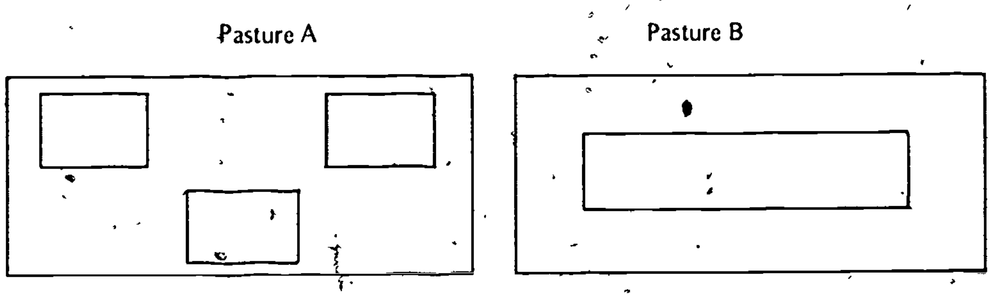
4.3.1 AREA: CONSERVATION

4.3.1.1 Direct the student to arrange 48 congruent paper squares on a table so that they form two large rectangles of 24 squares each. Rearrange the squares of one rectangle so that space appears around each square. Have the student decide which group of squares covers more of the table.

4.3.1.2 Have students construct four different rectangles such that each region has an area of 24 square units. This may be done with coordinate paper, with a geoboard or with square pieces of paper, as in 4.3.1.1. To relate this activity to length, ask students to find the perimeter of each of their rectangles.

4.3.1.3 Provide students with 16 paper right triangles, all the same size and shape. Ask the students to put them in two equal piles. Have them place the triangles from one pile next to each other on the table so that some kind of shape is created. Then have the students build a different shape with the triangles from the other pile. Do the two shapes have the same area? If the answer is "yes," ask students for an oral explanation. Finally, show students the areas are the same, either by rearranging one group of triangles to match the other or by putting the triangles from one shape on top of the triangles in the other.

4.3.1.4 The "Fields of Grass" problem:



Pastures A and B have equal area. If the three barns on pasture A were placed together they would just cover the same area as the one barn on pasture B. Which pasture has more grassland? Have students prove their answer. They may illustrate it with drawings, cutouts, felt board or lake and island board.

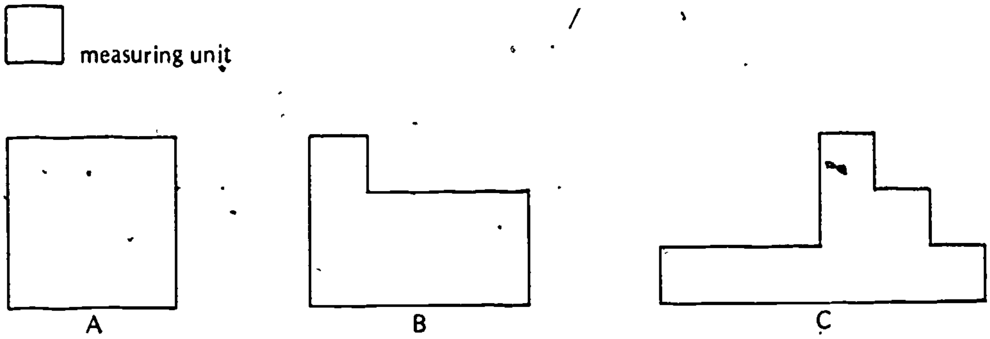
4.3.2 AREA: COMPARISON

4.3.2.1 Have each student draw an outline on a piece of paper around his/her hand or foot. Have classmates compare hand sizes. Then instruct students to hold two outlines against a window pane, place one over the other, and compare hand or foot sizes with those of their classmates.

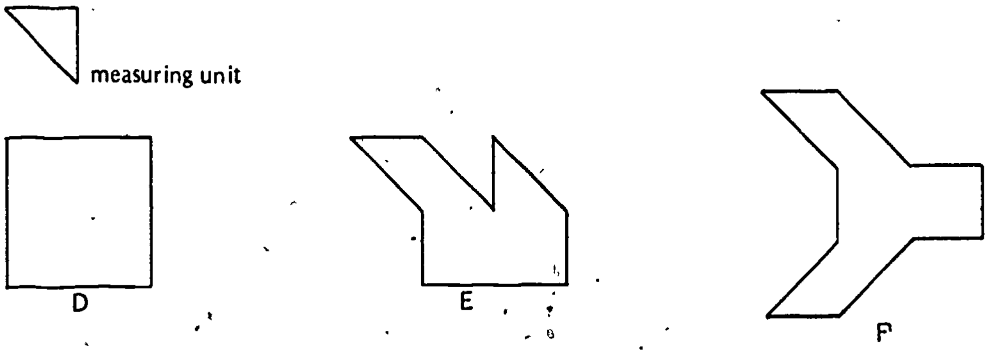
4.3.2.2 Distribute a picture to each student. On the picture have the student circle some specific items, for instance, the largest ball or smallest person. Next, have the student find larger or smaller items of the same kind in other pictures. This exercise will help students learn to compare sizes of objects in pictures. It will also help develop their vocabulary.

4.3.2.3 Have students compare large areas by counting off the number of smaller units (squares or triangles) in each. Give the students a unit square and a unit triangle. Have them place the measuring unit on the drawings and trace around it until the whole area has been covered. Then count the number of units in each region. Order the three regions from smallest to largest or largest to smallest. For convenience, this activity may be done on graph paper.

Sample 1:



Sample 2:



4.3.3 AREA: UNIT CONCEPT

4.3.3.1 Arrange for the class to view Program 5 of *MeasureMetric* and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide* and/or the activities below.

4.3.3.2 Have students determine the area of a tabletop in terms of sheets of paper, linoleum tiles, erasers, newspapers, books, towels, notebooks, blankets and other objects. Discuss the advantages and disadvantages of the various units used. Have students try to communicate measures via telephone or letter.

4.3.3.3 Have students determine the area of a tabletop in terms of rectangular sheets of paper, squares, triangles, trapezoids, circles, pentagons and irregular shapes. Discuss advantages and disadvantages of the various units used. Instruct the class to try to communicate the measurements by telephone or letter.

4.3.3.4 Have the class determine the area of a tabletop, a floor, a notebook cover and the school grounds in terms of little squares, middle-sized squares, large squares. Discuss the advantages and disadvantages of the various units used.

4.3.3.5 Have the class measure a wall or floor or football field in terms of sheets of newspaper. Try the measuring with different sized newspapers.

4.3.3.6 Supply students with precut figures of squares, rectangles, triangles, parallelograms, trapezoids, circles and irregular combinations of these shapes. The figures may have whole number or fractional dimensions, such as 3.2, 3.5 or 3.95, according to the needs and developmental levels of students. The cutouts may be made of cardboard, tagboard, plastic or a similar substance. Students also need graph paper.

After the students have received their figures, ask them to choose an area unit and outline it on their graph paper. Place the precut figures on the graph paper and draw around the various shapes. Have students count the number of their chosen units enclosed by each boundary. This process will probably create problems related to approximating and to the lack of a common unit. It also presents an opportunity to practice estimating and then counting.

As an alternate activity, ask students to outline or draw a number of shapes which all have the same area.

4.3.3.7 Have each team of students select a nonstandard unit to measure the area of the floor and the area of the teacher's desk top. Have teams decide if they want to use the same size unit to measure both areas. After the teams have determined the two areas, have each prepare a letter in which it places an order with a supplier for carpeting and formica. Ask the teams to read the letters out loud to see if they contain sufficient information to fill the orders. When students have discovered a communication problem (a need for standard units), ask them to develop a plan for solving this gap.

4.3.4 AREA: STANDARD UNIT

4.3.4.1 Arrange for the class to view program 6 of *MeasureMetric* and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide* and/or the activities below.

4.3.4.2 Supply students with precut figures of squares, rectangles, triangles, parallelograms, trapezoids, circles and irregular combinations of these. The figures may or may not have whole number dimensions. The cutouts may be of cardboard, tagboard, plastic or similar substances. Students also need graph paper with a centimetre scale.

Ask students to outline a unit of one cm^2. Then have them place the cutout figures on the graph paper, draw around the various shapes and count the number of one cm^2 units enclosed by each boundary. Students will have to do some approximating. Encourage them to estimate before measuring.

Extension: Have students develop mathematical expressions for the area of different shapes, for example, $A = l \times w$ for the area of a rectangle.

4.3.4.3 Make centimetre graph paper available. Have students trace the outline of their hands or feet and calculate the number of square centimetres they cover. Lead a discussion about approximating. Have the class trace around a cube and determine the area of one face of the cube. Ask the class if it matters how the cube is placed on the graph paper. What is the total area of all faces of the cube?

4.3.4.4 Students may construct their own area ruler or grid with which to measure area. Construct a centimetre scale grid on a sheet of clear plastic. A unit is a one-by-one cm square. Have students place this sheet on various drawings and find the areas by counting the squares within the boundary. The drawings may include squares, rectangles, triangles, parallelograms, trapezoids or combinations forming irregular shapes.

4.3.4.5 Provide students with a partial set of Cuisenaire rods consisting of four ten-rods (orange) and 15 one-rods (white). Several boxes are also needed. The length of each must be more than 40 cm but less than 55 cm. The width of each must be more than 15 cm but less than 40 cm. Each length and width should be a whole number of centimetres, not a fractional amount.

Have students use the rods to discover a plan for finding the area of the bottom of each box. Answers should be presented as a drawing which shows the learner's plan rather than a numerical answer. If Cuisenaire rods are not available, cardboard cutouts may be used. Extension. Have the more adventurous students develop a plan for determining the area of triangles, parallelograms, trapezoids and other shapes.

4.3.5 AREA: APPLICATION

4.3.5.1 Arrange for the class to view program 7 of *MeasureMetric* and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide* and/or the activities below.

4.3.5.2 Supply students with precut figures or actual-size drawings of squares, rectangles, triangles, parallelograms, trapezoids, circles and irregular combinations of these. According to the needs and learning levels of the students, the figures may have dimensions of whole numbers or fractional parts, such as 3.5. Use cardboard, tagboard or plastic for the cutouts. Supply students with metric rulers. Decide whether to have the students use formulas or the plan developed in 4.3.4.5. Ask the students to measure the figures and determine the area of each. Use the area ruler constructed in 4.3.4.4 for verification.

4.3.5.3 Supply students with centimetre graph paper. Have them construct, shade or draw as many different rectangles as possible with an area of 24 cm^2 and a length which is a whole number of centimetres. Have the class determine the perimeters of these rectangles. This activity may be done on geoboards if the nails are at one cm distances. Have students construct rectangles of the greatest possible area and the least possible area, each having a given perimeter, say 16 cm. Extension: Instruct the class to tie a string in a loop of 24 cm and place it on graph paper to determine the shape of the figure having the greatest area within the string. Find the approximate area of that figure.

4.3.5.4 Play the "mystery measurements" game, using area measurements. See directions in 4.1.5.8.

4.3.5.5 Have teams of students develop a plan for redecorating their classrooms. After choosing appropriate metric measuring devices and units, have each team measure and determine the materials needed to carpet the floor, paint the walls and ceiling, prepare drapes for the windows, and cover the teacher's desk and a classroom table with formica. Have teams write or phone their orders for materials to another team to see if communication is possible.

4.3.5.6 Ask the students to determine the area of an irregularly shaped object, such as a leaf. Next, have them find the mass of a sheet of graph paper, determine the number of squares on the page and calculate the mass for one square. Now, instruct them to trace the leaf pattern on the graph paper, cut it out and find the mass of the cutout. Compare its mass to that of one square to determine the number of squares covered by the leaf. (Be alert for possible confusion between the quantities of mass and of area when mass measurements are being used to determine area.) Compare the results found by this method to those determined by counting the squares inside the outline of the leaf. Students may prefer to use heavier material like tagboard, railroad board or cardboard and then draw a metric grid on the material.

4.4 CONCEPT IV: VOLUME

4.4.1 VOLUME: CONSERVATION

4.4.1.1 Have students balance one group of blocks with a different group. Do the groups still balance if you build one group into a house?

4.4.1.2 Provide five containers of about equal capacity but distinctly different shapes. Provide a sixth container with a capacity smaller than the smallest of the others. Use it as a "standard." Pour one "standard" of liquid or granular substance into each of the five containers. Compare and discuss the heights of the substance in the five containers.

4.4.1.3 Have students pour a quantity of liquid or granular substance from a short, wide glass into a taller, narrower glass. If necessary, pour the volume back and forth several times to show that the volume does not change when the shape changes. Use a half-gallon milk carton cut off at a line about 10.3 cm from the bottom and a one-quart milk carton cut off at the upper fold. Each will contain about one litre. Have students pour from one container into the other. Jars and cartons of various shapes and sizes can also be used.

4.4.1.4 Have students pour about 650 m*l* of colored water into each of two containers which are the same size and shape. Label them A and B. Assemble four tall, narrow glasses and four short, wide glasses or cups, too.

a. Ask if A and B contain the same amount of water. Adjust, if necessary, until the learner agrees that they do.

b. Pour all the water from A into the four narrow glasses. Ask whether the liquid in the four glasses combined or the liquid in B is greater in volume.

c. Pour all the water from the four narrow glasses back into container A. Then pour all of it from that container into the four wide glasses. Ask whether the liquid in the four glasses or the liquid in B is greater in volume.

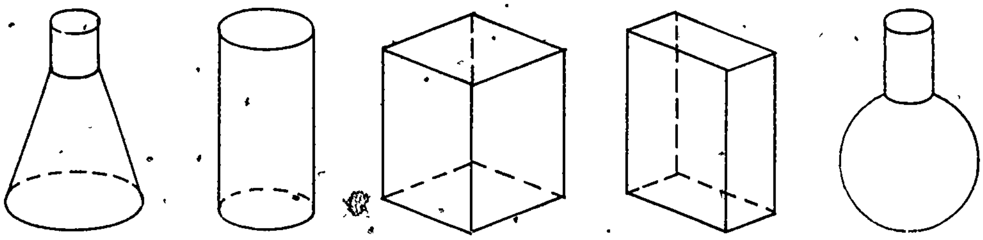
d. Pour all the liquid from B into the four narrow glasses. Ask which set of glasses contains a greater volume. Verify by pouring from each set of glasses back into the original containers and comparing again.

4.4.1.5 Ask the students to predict what will happen when a solid cylinder of aluminum is placed in a container of water and then replaced with a solid cylinder made of another material. Note that the cylinders must always be the same size and shape. They can be cut from rods of different materials, for example, aluminum, steel, plastic and wood. These are obtainable from local metal shops, lumber yards and craft stores. Verify the predictions by measuring the mass of the water displaced by each cylinder as it floats or submerges in the water.

4.4.2 VOLUME: COMPARISON

4.4.2.1 Arrange for the class to view program 8 of *MeasureMetric* and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide* and/or the activities below.

4.4.2.2



Provide five containers of various shapes as illustrated. Have students order them from largest to smallest volume by guessing. Verify by using a liquid or a granular substance which can be poured.

4.4.2.3 Provide students with a variety of differently shaped containers. Teachers may wish to choose sizes to include 250 m*l*, 500 m*l*, one *l*, one pint and one quart. Label the containers A, B, C, D and E respectively, but do not indicate the volumes. Have students use a granular substance or water to fill the containers. Some pouring back and forth should be encouraged as part of the process of comparing volumes. Then have them order these five containers from largest to smallest. Extension. Help students discover which containers are equal to multiple amounts of a smaller container.

4.4.2.4 Provide students with hollow models of cubes, rectangular prisms, triangular prisms, square-base pyramids, cylinders, cones and spheres. A funnel will also be helpful. The cubes and square-base pyramids should have equal bases, and the length of their bases should equal the diameters of the cylinder, cone and sphere. Have students compare the volumes of the three-dimensional figures by filling one with water, sand or beans and then pouring into the other containers. Extension: Help those students interested to discover specific volume relationships among the models.

4.4.3 VOLUME: UNIT CONCEPT

4.4.3.1 Arrange for the class to view program 9 of *MeasureMetric* and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide* and/or the activities below.

4.4.3.2 Show students one container holding a given amount of water—three to five vialfuls. Ask them to determine how many vialfuls were poured in. Begin with full vialfuls and then try half vialfuls. Switch to units other than a vial.

4.4.3.3 Ask students to determine the volume of a box in terms of books, bricks, candy cartons, toy blocks, Cuisenaire rods, cereal boxes, packing cases for refrigerators and other units. Discuss advantages to be gained by choosing a convenient unit. Have the class communicate such measures via telephone or letter to discover the communication difficulty when such nonstandard units are used. Students, for example, may place orders for quantities of material to be purchased.

4.4.3.4 Ask students to determine the volume of a box in terms of toy blocks, golf or ping-pong balls, cans, milk cartons, perfume or pop bottles, cylindrical tiles and other units. Discuss advantages to be gained by choosing a convenient unit. Have students communicate the measures via phone or letter as in 4.4.3.3.

4.4.3.5 Have the class determine the volume of several different sized boxes, of the room or of the gymnasium in terms of Cuisenaire rods, toy blocks, middle-sized cubes and large cubes. Discuss the advantages to be gained by a convenient choice of units in each case.

4.4.3.6 Provide an eye dropper, a measuring spoon, three containers (small, medium, large) and water. Using the eye dropper, have students find how may drops of water fill the measuring spoon. Then have them find how many spoonfuls are needed to fill the small container. Pourings from the small to large container are permitted. Calculate the drops required to fill the largest of the three containers. Explain how the answer was obtained.

4.4.3.7 Formulas or recipes given in "parts" emphasize the need to understand measuring units. Have students become familiar with this idea through making play-doh, bread dough, cookies, punch, finger paint or papier-mache. The class might want to try the following recipes:

Chemical Garden

1 part household ammonia
3 parts water
3 parts table salt
3 parts bluing

Mix together and pour over rocks, sand, sponges, wood or bits of brick. Spread the substance out on a metal tray. Let stand. Watch the crystals grow.

Punch

1 part fruit concentrate
4 parts water
1 part sugar

Ask students the following questions:

How much will the pitcher hold? How many little cans of concentrate should be used so the pitcher will be filled with punch? How many cans of water will be needed? How much punch is needed to serve the class? Suppose everyone wants "seconds"? Suppose half the class wants "seconds"?

4.4.4 VOLUME: STANDARD UNIT

4.4.4.1 Arrange for the class to view program 10 of *MeasureMetric* and participate in appropriate pre-program and post-program activities selected from *MeasureMetric Teacher's Guide* and/or the activities below.

SUMMARY: *MeasureMetric* *

AIT's *MeasureMetric*	Concept and Level as found in *MEASUREMENT . . . with Metric*	Page number where found
Program 1	Introduction to Measurement	18
Program 2	Length, unit concept	19
Program 3	Length, standard unit	20
Program 4	Length, applications	22
Program 5	Area, unit concept	31

**MeasureMetric*, Agency for Instructional Television, Bloomington, Indiana, 1976.

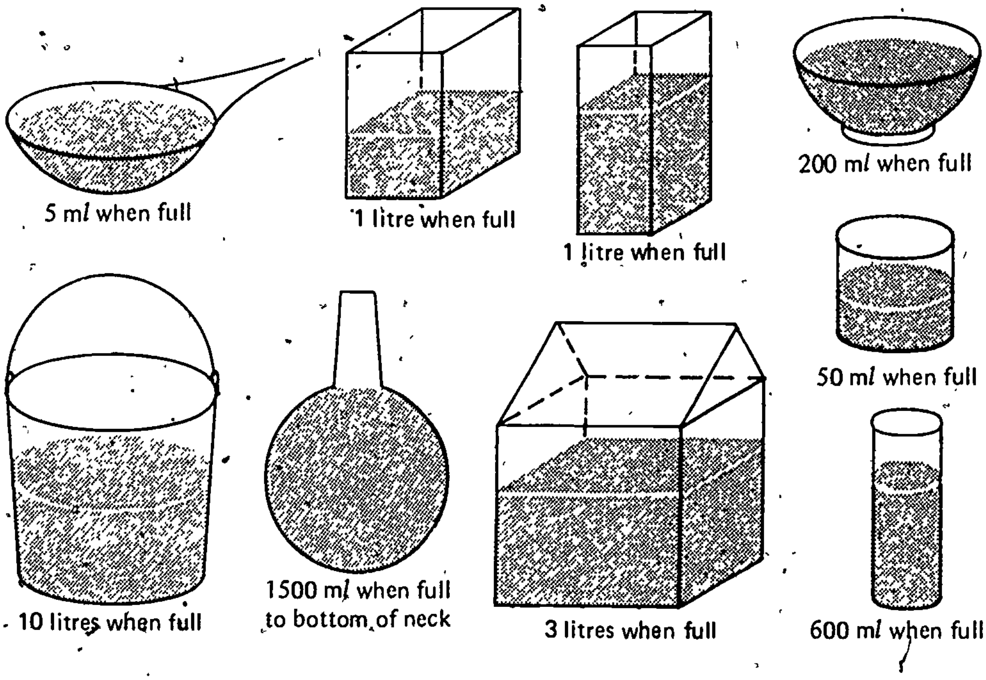
Program	6	Area, standard unit	32
Program	7	Area, applications	33
Program	8	Volume, comparison	35
Program	9	Volume, unit concept	35
Program	10	Volume, standard unit	36
Program	11	Mass, unit concept	26
Program	12	Mass, standard unit	27

4.4.4.2 Provide each team with three or four bottles or jars of various shapes and sizes from 100 m*l* to 1000 m*l*. Throwaway I.V. bottles from the local hospital may be used. Ask students to observe the numbers and lines on the I.V. bottles. They should find numbers for 100, 200, 300, . . . 1000 m*l* with small marks between those designating the units of one hundred. Ask students what the small marks indicate. Then ask students what amounts are approximated when the water level is halfway between two of the smaller marks.

Have students list some of the amounts that can be measured with the I.V. bottle, for instance, 600, 625, 650, 675 and 700. What metric unit will be involved with the number 625? Now have the teams estimate the volume of their other bottles to the nearest 25 m*l*. After their estimations are recorded to the nearest 25 m*l*, have teams use the I.V. bottles to verify the estimates. This activity could be done as an estimation contest with points awarded for estimates within 25 m*l*, 50 m*l* and so on.

4.4.4.3 Have the class estimate the amount of liquid in partially filled containers of known capacity. Get one estimate in terms of litres and one in terms of millilitres for each container. After the estimates have been recorded, have students measure the liquid by pouring it into calibrated containers. This activity may be done as an estimation contest. Award team points for estimates within 1 *l*, 500 m*l*, 100 m*l* and 10 m*l*.

4.4.4.4 Have students determine the volume of objects in millilitres and in cubic centimetres by noting the amount of water displaced by the object. The objects should be small, sinkable ones, of either regular or irregular shapes. Have students estimate the volume of the objects in millilitres and in cubic centimetres, then verify their estimates by immersing the objects in water in a graduated container. Have students calculate the difference in the water level to find the object's volume in millilitres. Students may already know one cm^3 of water is one m*l*. If they do not, use measurements of the regular objects to calculate the capacity in cubic centimetres. Compare the result to the volume in millilitres. After students have discovered the relationship, they can find the cubic centimetres in irregular objects easily.



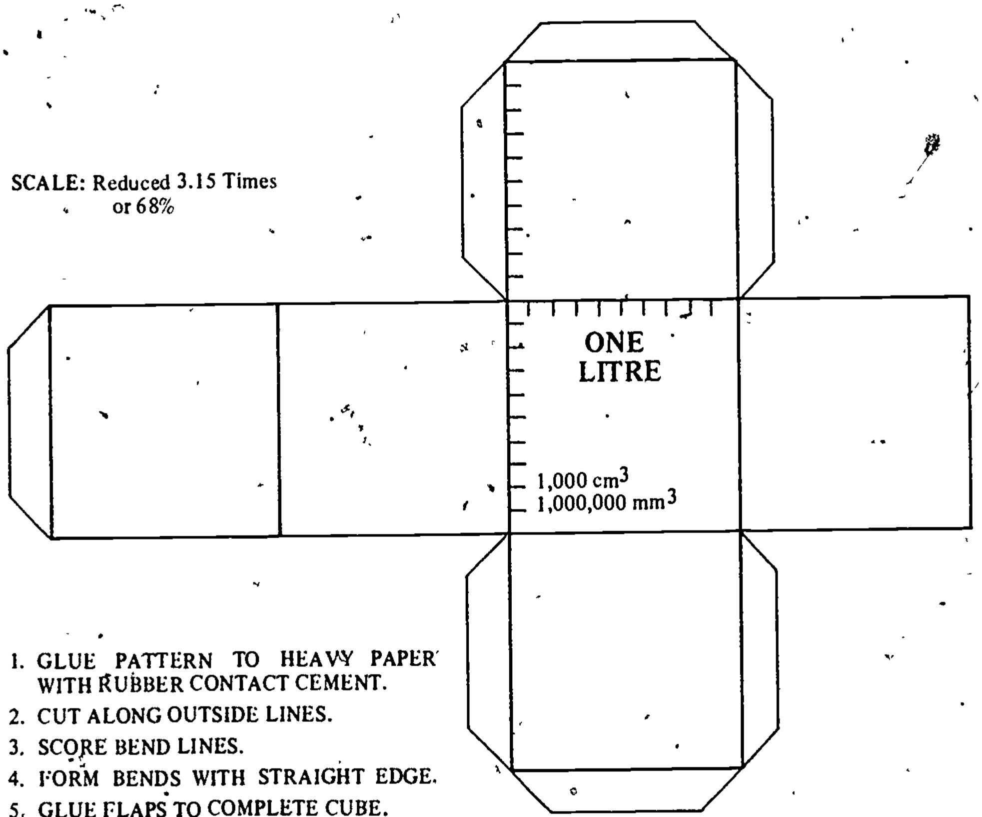
4.4.4.5 Hold an estimation contest. Obtain a set of calibrated measuring containers and a collection of containers of varying sizes and shapes. Include shampoo, mouth wash, hand lotion, detergent and syrup bottles, ice box containers, jars and milk cartons. Some containers should have regular shapes and some irregular ones. Arrange the containers in pairs so that the volumes are different, but not noticeably so. Have students estimate which container in each pair has the greater volume. After students have recorded their guesses, instruct them to verify the guesses with calibrated measuring containers. A scoring system may be used to determine the "champion guesstimater."

4.4.4.6 Hold a prediction contest. Place several sponges of various sizes in a bucket of water. Insert a funnel into a graduated cylinder. Have students grab a sponge with one hand only, hold the sponge over the funnel and squeeze as much water as possible out of it using only one hand. Read the amount of water in millilitres. After sufficient practice have the students predict the amount, record it, perform the event, record the actual amount and determine the difference between the two amounts. Extension: If the class comprehends the displacement principles, try another, more challenging prediction event, using sinkable objects of varying size and shape. Have the class estimate the volume of the objects and record their estimates. Then verify the estimates by measuring the amount of water each object displaces.

4.4.4.7 Conduct a unit recognition test. Obtain five cubes whose volumes vary from each other by about 15 percent. One should have a volume of one *l*. Have students guess which cube that is. Do this with cylinders, too. Use cylinders which vary only in diameter or in height, not both dimensions.

4.4.4.8 Sponsor a test-your-eye game. Assemble one graduated container, a set of three differently shaped glasses, a set of three differently shaped bottles and a larger, irregularly shaped, unmarked container. Have students follow this game procedure: Put an amount of water in the large, unmarked container. Pour all of that water into the three glasses so that each glass has the same amount. Pouring back and forth among the three glasses to try to adjust the amount is permitted so long as the graduated container is not used. Check the result by pouring the water, one glass at a time, into the graduated container. Record the results. Play the same game using the set of three bottles.

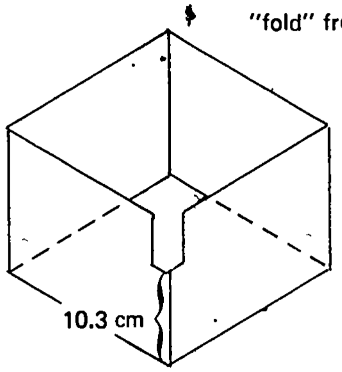
SCALE: Reduced 3.15 Times
or 68%



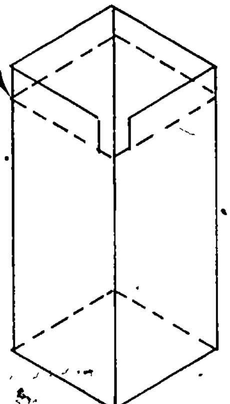
1. GLUE PATTERN TO HEAVY PAPER WITH RUBBER CONTACT CEMENT.
2. CUT ALONG OUTSIDE LINES.
3. SCORE BEND LINES.
4. FORM BENDS WITH STRAIGHT EDGE.
5. GLUE FLAPS TO COMPLETE CUBE.

4.4.4.9 Have students make a cubic decimetre either by cutting out six squares, each 10 cm by 10 cm, and taping them together to form a cube, or by laying six squares out on a single sheet of material and then folding and taping the paper to form a cube. What is another name for the capacity of the cubic decimetre? If the class does not know, have it fill the cube with a quantity of granular material which has been measured in a standard litre container. Ask students to find a way to measure 100 cm^3, 200 cm^3, and so on, using their own cubic decimetre. The foregoing scaled-down drawing designed by the Graphic Arts Department at Chemeketa Community College shows one plan which fits nicely on a regular sized file folder.

4.4.4.10 Have class make a litre container from a two-quart milk box by cutting it off so the bottom edge of the corner "spout" is 10.3 cm from the bottom of the box. Students can also use a one-quart milk box if they cut it so the bottom edge of the corner "spout" is at the upper fold. See drawings:



(from 2 quart box)



(from 1 quart box)

4.4.5 VOLUME: APPLICATION

4.4.5.1 Supply students either with a set of three-dimensional solids of cubes, rectangular prisms, triangular prisms, spheres, cylinders and other shapes or with cardboard boxes of varying sizes and shapes. (Mill ends from a sawmill are excellent for this activity.) Obtain metric rulers for the class, too. Decide whether to provide formulas. Ask the students to measure the figures, then calculate the volumes. For review, ask students to determine the surface area and/or draw a "cover" for the entire three-dimensional figure on paper.

4.4.5.2 Have the class play "mystery measurements," using volume measurements. See directions in 4.1.5.8.

4.4.5.3 Have students indirectly measure the volume of an irregular, solid rock. First, have them pour water into a graduated cylinder to a predetermined point and record the water level. Then have them immerse the rock in the water, note the change in water level and record the new level. Determine the volume of the rock in millilitres and/or cubic centimetres.

4.4.5.4 Ask a team of six students to divide a quantity (approximately a half litre) of fruit juice equally among the team members. Provide the team with a 100 m*l* graduated cylinder, a 10 m*l* graduated cylinder, a dropper and six cups of different sizes and shapes. When the group has successfully completed the activity, permit it to drink the juice.

4.4.5.5 Ask students to determine how many eyedropper drops of water are in one millilitre; then have them determine the number of millilitres in a teaspoon and in a tablespoon. Extension: By using results from above, find how many eyedropper drops of water fill a tablespoon. Find how many litres of water are in one million drops of water.

4.4.5.6 Supply learners with an orange Cuisenaire rod and a graduated cylinder. Have them measure and compute the volume of the orange rod. After they have done so, have them submerge the

rod in a measured quantity of water in the graduated cylinder; have them note the new water level and compute the volume of water displaced by the rod. Compare this figure with the computed volume of the rod. Extension: Have the class determine the volume of a variety of small, sinkable objects by this method. Encourage students to estimate volumes as well. Hold an estimation contest.

4.4.5.7 Have the class make one serving of Metric Fruit Punch by using the following recipe: Measure five ml of orange, five ml of lemonade and five ml of cherry imitation soft drink mix in a cup. Add 120 ml of ice-cold water. Stir and enjoy.

4.4.5.8 Have the class make one serving of Metric Hot Chocolate by using the following recipe: Measure 120 ml of water into a pan and heat to about 100°C. Measure 15 ml of cocoa mix into a mug. Add boiling water. Stir and enjoy.

4.4.5.9 Have the class make Metric Marshmallow Krispies by using the following recipe: Melt 60 ml margarine over a low heat, add 720 ml minature marshallows, stir until melted and blended, remove from heat and stir in 1.25 l (1250 ml) Rice Krispies. Cool before cutting.

Many more recipes using metric measurements are found in *The Oregon Mathematics Teacher*, Special Edition Metric Cookbook issue, published by the Oregon Council of Teachers of Mathematics. A limited number of copies is available for $1 each. Contact Don Fineran at the Department.

4.5 CONCEPT V: TEMPERATURE

This unit on temperature has not been broken down into exercises on conservation, comparison, etc., as the other units have. These concepts are implied in the order in which exercises are presented in this unit.

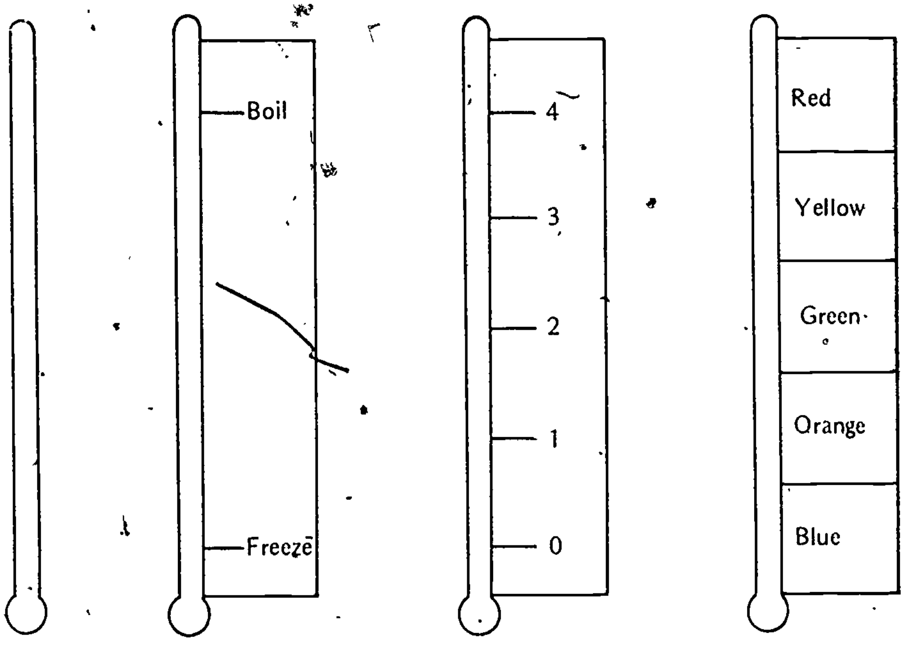
4.5.1.1
(a) Have students find pictures which show the concepts hot and cold. Discuss the pictures with them.

(b) Present several pictures which show the concepts hot and cold. Ask the students to order them from hottest to coldest. Discuss.

(c) Have students draw pictures which show cold, cool, warm and hot weather. Discuss.

4.5.1.2 The following activity will help learners discover that an instrument is needed in order to obtain accurate temperature readings. Provide containers of water, A hot, B at room temperature, and C cold. The child feels the water in A, then immediately feels the water in B with the same finger, then describes the temperature of the water in B. Next the child feels the water in C, then with the same finger immediately feels the water in B and describes what seems to be the temperature of the water in B. Discuss whether feeling the water to determine its temperature is reliable.

4.5.1.3 Provide an ungraduated liquid-in-glass thermometer to make arbitrary units of temperature. Have a student place the ungraduated thermometer in a mixture of ice and water and then in a container of boiling water. The freezing and boiling points should be marked on the thermometer stem with a grease pencil. Have a student subdivide the distance along the stem into equal units between the two fixed points. Assign numbers to specific points on the scale. Keep in mind that number skills are needed for the above. It may be easier to use a color-coded temperature scale for five-and-six-year-olds. (See diagram.)



4.5.1.4 Have the learner measure the temperature of two pans of water. The temperature of the two pans should differ by at least 10°C. Then give the student a third pan of water that is still another temperature. Have the learner estimate the temperature of the water in each pan by feeling it. Then have him or her order the three pans of water from the coolest to the warmest. Verify the ordering with the student-made thermometer.

4.5.1.5 Have students estimate temperature in the following situations, first, by feeling, then by using a Celsius thermometer:

Group 1: Cold tap water, hot tap water, ice water, ice water with salt.

Group 2: Air temperature in the classroom near the ceiling, in the classroom near the floor, near the surface of a radiator, hallway, outside temperature in the sun, outside temperature in the shade, in a refrigerator, in a freezer.

4.5.1.6 Have students record the daily temperature either with the thermometers made in class or with a Celsius thermometer. Extension: Graph the readings taken at the same time of day over a period of time.

4.5.1.7 Place equal quantities of boiling water in containers such as coffee mugs, styrofoam cups, tin cups, aluminum pans, thermos jugs, ordinary bowls and heavy soup bowls. Let the water stand and have students take readings with a Celsius thermometer at five minute intervals and record the results. Use equal quantities of water. Extension: Graph the results as well. Have the class predict the results if it were to start with ice water. Verify.

4.5.1.8 Help students make a simple air thermometer. Have them put one end of a piece of clear tubing in a jug and the other in a pan of colored water. Warm the air in the jug and let the water rise in the tubing as the air in the jug cools. Instruct the class to mark water levels on the tubing when the water in the pan is at a cold, a cool, a comfortable and a very hot room temperature.

5. TEACHER WORKSHOPS

5.1 AIM AND FOCUS

This section is intended as a guide for instructors who are planning a metric workshop for either teacher or nonteacher participants. Generally speaking, teachers teach as they were taught. Teacher workshops, therefore, should be conducted in the same manner in which teachers will work with their students. The workshop activities should be of the kind which can be used in classrooms. One way to assure that the workshop is useful is to include teachers in the planning step. In addition, asking these five questions may be helpful:

1. Will the workshop be measurement oriented?

2. Will the workshop stress "hands-on" activities?

3. Will the workshop emphasize the importance of estimation?

4. Will the workshop emphasize the importance of avoiding conversions while teaching measurement?

5. Will the workshop demonstrate that an effective and interesting measurement program can be taught with low-cost equipment?

5.2 WORKSHOP PLANNING

Besides the five questions just listed, workshop planners should consider four major steps:

1. Preliminary planning decisions (objectives)

2. Workshop organization (agenda, materials, activities)

3. Workshop procedures

4. Follow-up (immediate evaluation, intermediate evaluation, future needs)

Preliminary Planning Decisions:

Following are some questions the instructor or workshop instruction team will need to consider in planning:

1. Who should choose and develop the workshop objectives a) the instructor and participants or their representatives or b) the instruction team and participants or their representatives?

2. Who will be invited to attend the workshop? Is attendance voluntary?

3. Will the background of the metric system be covered, if only briefly?

4. How will justification for the transition to the metric system be handled?

5. What learning approach will be implemented? Is the CONTINUOUS NONGRADED MEASUREMENT LEARNING APPROACH an alternative?

6. How will the basics and the vocabulary of the metric system be presented? What handouts will be used?

7. Which levels of measurement learning should be stressed? Conservation? Comparison? Use of nonstandard units? Use of standard units, namely SI?

8. Which concepts of measurement (length, mass, area, volume, temperature) should be developed?

9. Will the workshop help teachers to appreciate the simplicity of a decimalized measurement system? Will the base ten nature of the system be developed? Will the relationships among length, volume and mass be considered? Will the computational advantages of using decimal fractions become evident?

10. How will workshop leaders develop an awareness of and the need for using manipulatives, aids, games, etc., to teach measurement?

11. Will the workshop leaders operate on a THINK METRIC basis? Will they acquire a feel for common metric units to the point of estimating in terms of those units? Will they comprehend distances and quantities expressed with metric units?

12. Will the workshop agenda include time to consider the implications that changing to a metric system will have on all curricular areas, in particular, mathematics, science, home economics, industrial arts, vocational-technical and social studies? For example, decimal fractions may be introduced sooner than they are now.

13. Will workshop leaders consider ways in which the general public can be made aware of the metric system? Will leaders consider helping the general public learn to use the SI units?

14. Will the workshop include time to begin planning metric information for parents?

15. What resource personnel may be needed? (See "Resource People," p. 48.)

5.3 WORKSHOP PLAN

The instructor or team will want to have a general plan of action prepared. Some items for consideration are:

5.3.1 Organization

1. The instructor or team should work with representative participants in planning the major agenda and various activities.

2. A brief assessment of participants' knowledge of the present measurement system might be made. (See sample assessment instrument at the end of this section, p. 47.)

3. The following items should be considered: Time, place, room, tables, number and teaching level of participants, participant needs (cooking and sewing for home economics teachers, measuring shop construction projects for industrial arts teachers and a variety of measurement applications for coaches and teachers of social studies, health, driver training, physical education, and so on).

5.3.2 Instructional Materials

1. Leaders should have a sufficient quantity on hand to permit participants to work in groups of two.

2. They should use homemade materials, made by themselves or by participants.

3. They should ~~plan~~ a variety of materials for working with different measurement concepts at various learning levels.

4. They should provide handouts on metric background, history, trends and current status.

5.3.3 Activities

1. Leaders should select activities that will be fun for the participants to try.

2. They should choose appropriate activities for the specific group in the workshop for example, primary teachers, elementary teachers, businessmen or homemakers.

3. They should use activities that participants can adapt for their own use in their classrooms, at work and at home.

5.4 WORKSHOP PROCEDURES

Workshop procedures should include:

1. Have every participant actively involved in all activities. Groups of two are suggested. Team competition is popular.

2. Provide sufficient time for all participants to discuss and evaluate the activities.

3. Relate each activity to appropriate learning level(s).

4. Include some humor and some "interest getters," for example, door prizes for "meritorious metricating," ten-cent fines for using customary units in conversation, awards for enthusiastic performance.

5.5 EVALUATION AND FOLLOW-UP

Evaluation of the workshop may take the form of demonstration activities, questionnaires or discussion of pre-test/post-test techniques. Planners may want to consider the following points:

1. The form of the workshop evaluation should make sense to participants. An evaluation might include demonstration of measurement activities, development of activity lab cards, questionnaires, discussions, pre-tests/post-tests.

2. Instructors or teams should decide whether they are willing to share the workshop evaluation with the ODE Metric Coordination Committee. The committee would like to incorporate ideas in plans for future workshops.

3. A very useful workshop evaluation exercise might be to ask participants to demonstrate competence by writing activities which are appropriate to their teaching levels and which illustrate consistency with the developmental learning levels of students. This approach should provide materials that teachers may take back to their classrooms.

4. A questionnaire might ask the participant to rate their understanding of metric concepts on a graduated rating scale before and after the workshop. It might also ask participants to rate the effectiveness of the workshop. Provision for rating the workshop materials should be included.

5. If discussion is the method used, participants may help decide how well the workshop met the objectives previously developed. Further discussion might focus on learning approaches, advantages of the metric system, functions of estimation, metric units and prefixes, useful measurement activities and "thinking metric."

6. A pre-test and a follow-up post-test might be used to compare levels of competency before and after the workshop. Understanding of learning stages as well as measurement concepts should be considered.

7. Teachers may run into problems as they begin teaching the metric system. Planners should provide them with resource people who will be able to answer questions. News from both Canada and Australia and our own experiences indicate that a one-time metric workshop is not sufficient. Follow-up services should be scheduled early. Has local leadership for metric measurement education been identified?

5.6 SAMPLE ACTIVITY: THE PAPER STRIP

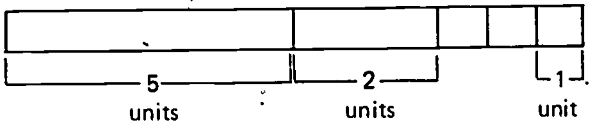
The following activity is offered as one "hands-on" workshop experience for teaching measurement based on developmental learning levels. This activity includes considerations at all five developmental learning levels while dealing only with the attribute of length.

5.6.1 GETTING READY

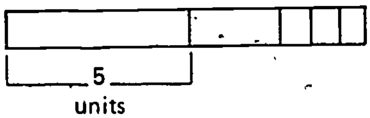
Materials need to be prepared in advance, in sufficient quantity to supply each workshop team of two people with four strips of paper equal in length: two red, one blue and one yellow. One of the reds, the blue and the yellow strips will be premarked in the following manner:

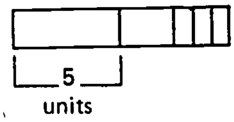
1. Select a "unit" which is between three and eight cm in length. Mark enough sets of one red, one blue and one yellow to supply about one-third of the teams. Mark the strips as in

the diagram so the longest part of each strip is equal to five units, the next part to two and the shortest to one of the chosen units.



2. Do the same for all other teams, making the "unit" different in each case from all the others and somewhere between three and eight cm. The strips for two teams might look like these:





5.6.2 CONSERVATION

Each team does the following:

1. Place the two red strips side by side to show their lengths are the same.
2. It moves one red strip to a new location and compares the lengths of the two red strips.
3. It bends one red strip into the shape of a V and compares the lengths of the two red strips again.
4. It forms a circle with one red strip and compares the lengths of the two red strips.
5. It cuts the marked red strip on the marks. It examines the length of the "train" formed when the cut red pieces are placed end to end. It compares the length of the "train" and the length of the uncut red strip.
6. It discusses the ages at which youngsters perceive conservation of length.

5.6.3 COMPARISON

The team cuts the yellow and blue strips on the marks, and using all the cut red, yellow and blue pieces:

1. It sorts all pieces by color, thus showing that color is one characteristic for comparing two objects.
2. It sorts all pieces by length. Size is another characteristic for comparing two objects.
3. It takes one piece of each length and makes a new arrangement from longest to shortest. It labels the longest *a*, the next *b* and the shortest *c*.
4. It mixes all unlabeled pieces into one pile and then finds all other pieces which are the same length as the strip labeled *a*. It labels each with an *a*. It does the same for *b* and *c*.
5. It discusses whether a child who does not yet perceive conservation of length can do such a matching exercise.

5.6.4 UNIT CONCEPT

Each team continues to use their materials from the above activities.

1. Using the unmarked and uncut red strip, show how many *a's* will equal its length. How many *b's*? Is it possible to represent the length of the uncut red strip by using only *b's*? Why or why not?
2. It determines if the *a* length can be measured only in terms of *b*, *b* length only in terms of *c*. The team demonstrates its conclusions.
3. Using the unmarked red strip, it finds the number of ways that this strip length can be represented by using combinations of *b* and *c*, *a* and *c*, *a* and *b*.

4. Instructor and teams identify as many objects to be measured as there are teams. They identify *a* as the unit of measurement for this activity. Each team measures all of the objects by using its own *a*. It records the results for comparison with other team results. A discussion should follow, revealing that some teams have the same (hopefully!) numerical results, while other teams do not.

5. Each team measures a small and a large object. It measures those objects three times, once in terms of *a*, once in terms of *b* and once in terms of *c*. It then discusses which unit, *a*, *b* or *c*, was found to be the most convenient for measuring the small object and the large object.

6. The team discusses those concepts which a child must have to do these kinds of activities and discovers the need for making appropriate unit choices.

5.6.5 DISCOVERING A NEED— STANDARD UNITS

Teams continue from earlier activities.

1. The teams are given a hypothetical situation. They must order classroom carpeting from a supplier by phone. The teams will attempt to communicate the room size in terms of their previously chosen *a*, *b* or *c* units.

2. When the teams discover that communications have broken down they should be led to the standard unit concept.

3. Teams should discuss creating situations in which students can discover a need for standard units.

5.6.6 METRIC SYSTEM AND APPLICATION

Continue teams as before: The two exercises below are a continuation of the three preceding exercises.

1. Workshop leaders should introduce some standard units of length, e.g., cm and m.

2. They should have the teams measure the room using an appropriate standard unit. A discussion should reveal that all teams (optimistically!) have the same results. Teams will then complete their carpeting order. Communication should now be possible.

Another workshop activity is a "quiz" on the old system of measurement. Try it. . . .!

5.6.7
QUIZ ON YE OLDE FAMILIAR (?) SYSTEM

Fill in the blanks with the appropriate numbers.

VOLUME

1. 1 quart = ______ pints
2. 1 gallon = ______ quarts
3. 1 barrel = ______ gallons
4. 1 gallon = ______ cubic inches
5. 1 peck = ______ quarts
6. 1 bushel = ______ pecks
7. 1 fluid ounce = ______ cubic inches
8. 1 fluid ounce = ______ drams
9. 1 pint = ______ fluid ounces
10. 1 cup = ______ fluid ounces
11. 1 tablespoon = ______ teaspoons

LENGTH

12. 1 foot = ______ inches
13. 1 yard = ______ feet
14. 1 rod = ______ yards
15. 1 mile = ______ feet
16. 1 chain = ______ feet

WEIGHT

17. 1 dram	= ______ grains	20. 1 ton (short)	= ______ pounds
18. 1 ounce	= ______ drams	21. 1 ton (long)	= ______ pounds
19. 1 pound	= ______ ounces		

AREA

22. 1 square inch	= ______ square foot	25. 1 acre	= ______ square feet
23. 1 square foot	= ______ square inches	26. 1 square mile	= ______ acres
24. 1 square yard	= ______ square inches		

Evaluation Criteria

Score	
24-26	Super genius. Any measurement system is your bag!
21-23	Above average. You probably remember anniversaries, birthdays.
18-20	Pretty good. You're ahead of the average bear!
17-0	Surprised? Have you thought about switching? . . . Or would you rather fight than switch?

ANSWERS

1. 2
2. 4
3. 31, 42 or 55 gallons
4. 231
5. 8
6. 4
7. 1.804
8. 8
9. 16
10. 8
11. 3
12. 12
13. 3
14. 5½
15. 5,280
16. 100 or 66
17. 27.344
18. 16
19. 16
20. 2,000 lbs.
21. 1.12 short tons
22. 0.007
23. 144
24. 1,296
25. 43,560
26. 640

Note to instructor: The above quiz may be used as a workshop activity provided it is presented as a nonthreatening activity—"just for fun." Participants should be encouraged to work together and discuss questions as they work. The quiz may permit participants to observe that they do not know all of the present system and yet they have been able to do any measuring they needed to do. Hence, it will not be necessary for everyone to learn all of the metric system either. The conclusion should hold for students as well as for adults. Teachers should take this into account as they decide what to teach.

5.7 RESOURCE PEOPLE

Many people in Oregon can serve as workshop resource personnel. A number have already made special preparations for conducting metric workshops. People from these institutions and organizations may be available:

1. Community colleges (most likely the institution in your area)
2. Colleges and universities
3. Division of Continuing Education
4. Intermediate education districts
5. Oregon Science Teachers Association
6. Oregon Council of Teachers of Mathematics
7. Oregon Vocational Association
8. Math Learning Center
9. Local school district curriculum specialists
10. Oregon Museum of Science and Industry
11. Oregon Home Economics Association
12. Business and industry representatives
13. State and federal agencies
14. Local experts

If you desire assistance in planning a workshop or in obtaining a workshop leader, the Oregon Department of Education Metric Coordination Committee can help you. The members of the committee are Ray Thiess, Specialist, Science Education; Don Fineran, Specialist, Mathematics Education; Ralph Little, Specialist, Trade and Industrial, Technical Education; and Jim Sanner, Specialist, Radio and Television.

6. METRIC CONCERNS FOR PARENTS

6.1 EDUCATOR'S RESPONSIBILITY

Parents of today's students want to learn about the school program being provided for their sons and daughters, i.e., subjects and teaching methods. And, as consumers, home owners and producers, they also want to learn survival-level metric skills. The educational community has a responsibility to assist parents in meeting both of these needs.

Several approaches are suggested below. The best program is undoubtedly a combination of several of the following:

1. A series of written communications—news releases, hand-outs, flyers, samples of student work, newsletters, articles for the local newspaper;
2. A parent's night metric program—open house, demonstrations by students or teachers, metric games, student displays;
3. A series of metric workshops for parents. One popular workshop has been the "Mini-Metric Olympics," which introduces concepts but concentrates on "hands-on" measuring and on estimating with common metric units;
4. A metric fair, metric week or metric night;
5. Joint efforts with other community agencies, e.g., County Home Extension Service, Community Schools Program, local media;
6. Joint efforts of parents and youngsters in workshops, metric fairs and other activities.

6.2 METRICS FOR PARENTS

As local educators assist in planning the metric information program for parents, a number of additional suggestions may be helpful:

1. Educators should keep lessons simple. It is not necessary to teach people the entire metric system before they begin using it. Teachers should begin with whatever parents need to meet their current needs.
2. Metric workshops for parents can be both popular and useful. In general, they should be similar to those for teachers. Workshops should:
   a. Provide "hands-on" measuring with metric units, using only the commonly used units;
   b. Encourage estimation with the common metric units—a vital step toward the THINK METRIC goal;
   c. Utilize a "fun and games" approach;
   d. Supplement activities with films, not the reverse!
   e. Provide simple, straightforward handouts;
   f. Respond to current needs in cooking, sewing, the home shop and retail products.
3. Educators should involve parents in planning. They should schedule different activities at various times, encourage parent participation in preparing materials and conducting workshops and involve local media representatives.

Meeting the two metrication needs of parents is essential to the long-term success of the metric movement. It is also an important part of each school district's public relations program. Local administrators and teachers can seek help from the resource people listed in 5.7, from local resource people and from the ODE Metric Coordination Committee.

7. METRIC PROGRAM IMPLEMENTATION

The decision to "go metric" is a major decision that involves the total school district. The success of a curriculum change of this scope depends on support and cooperation at all levels.

7.1 ADMINISTRATIVE DECISIONS

While school systems have different ways of implementing curriculum changes, there are certain areas of common concern. The district superintendent is the person who has the legal status to make curriculum decisions. It is imperative, therefore, that the superintendent and his/her administrative staff understand the demands of the project, including the demands on staff time. Some of the costs to be considered are compensation for release time and/or money to properly implement the change, needed consultant assistance, appropriate in-service education, and new material requirements.

7.2 STAFF INVOLVEMENT

"Going metric" is a decision that will involve the total school. The foremost group to be influenced is the students. Principals, supervisors, custodians, bus drivers, cooks and teachers are all involved. Common staff-oriented concerns include a lack of in-depth knowledge about curriculum goals, apathy, opposition to change, a lack of process skills, a lack of exposure to exemplary models and a lack of involvement in the decision-making process. Many of these concerns can be alleviated by involving administrators, local curriculum specialists and teachers from all disciplines, K-12, and other representatives of the entire staff on a curriculum committee that will develop curriculum meeting local needs. The group can look at the present curriculum and make needed changes at all levels.

7.3 COMMUNITY INPUT

Community input may be gained through a district advisory committee made up of people who are not teachers, school board members, parents and students. Such a committee will help plan the school curriculum, assess the needs of the general adult community and recommend programs for adult awareness.

7.4 SUCCESSFUL IMPLEMENTATION

To make a curriculum change like "going metric" successful, it is essential to develop a curriculum that meets local needs and to construct a specific strategy for implementing it. This strategy could include identifying all groups that will experience the impact of the change, developing a hierarchy of responsibility for those involved in the change, identifying the components of the program, constructing a timeline, obtaining all required guides, materials and equipment before beginning, and above all insuring that the philosophy and objectives of the change are understood by all concerned.

7.5 IN-SERVICE

An important part of the preparation for "going metric" will be to insure that all teachers feel comfortable using the metric system. A curriculum committee can anticipate in-service workshop needs and help plan the workshop. Workshops can be designed to include background in learning measurement theory, teaching measurement strategies, choice of teaching materials and information about the International System of Units. (The experience in some districts suggests in-service programs on metrication do not need to be extensive in time or cost.)

7.6 TEACHING MATERIALS

Teaching metric measurement can be done effectively and inexpensively. Some metric instruments are needed, but one advantage of the "hands-on" approach is that students can make their own measuring instruments. Lists of materials, commercial and homemade, are suggested here. Some textbooks and supplementary printed materials are available. Those used as references for this handbook are listed in the bibliography. The State Board of Education's metric education policy, which is endorsed by the State Textbook Commission, assures that basic textbook materials will be primarily metric, beginning with the 1976 adoption. The revised criteria will call for textbooks that present the metric system as the primary measurement system.

Commercial Materials:

Some commercial materials essential for teaching measurement with metric are metre sticks, metric rulers, metric tape measures, metric trundle wheels, calipers, a balance scale with set of metric weights (1 g to 1 kg), a platform scale in metric, calibrated beakers, flasks, vials, cylinders, a set of hollow, geometric models with metric dimensions, a set of blocks with metric dimensions, Celsius thermometer, metric graph paper, Cuisenaire rods and funnels.

Homemade, Collected Materials:

Some homemade or collected materials are string, ribbon, adding machine tape, masking tape, paper clips (large size preferred), sticks, molding, dowels, straws, cups, bottles, jars, cans, tubes, toy blocks, milk cartons, ordinary water glasses, cottage cheese containers or other refrigerator dishes, area pattern blocks, newspapers, sheets of notebook or construction paper, floor tiles, linoleum blocks, geoboards, water (and sink), sand (and sand box), beans, rice, play-doh, modeling clay and potatoes.

7.7 INVITATION TO WORK TOGETHER

The ODE Metric Coordination Committee anticipates the opportunity to work cooperatively with district people on metric education projects. The committee can assist districts in curriculum development and planning, in organizing workshops for teachers or general adult groups, in securing resource people for workshops, and in developing new learning activities or alternate approaches to teaching measurement.

7.8 TIMELINE FOR METRIC EDUCATION IN OREGON

Briefly, the Oregon Metric Education timeline is as follows:

1. June 1974 – Adoption of Metric Education Resolution by State Board of Education and State Textbook Commission.

2. 1974–1975 school year – Development of metric awareness workshops and materials for teaching metric measurements.

3. 1975–1976 school year – Continuation of metric awareness activities among educators, beginning of metric awareness for parents, beginning of metric system concept development, development of textbook selection criteria for the 1976 state textbook adoption. (All texts to be primarily metric beginning with the 1976 adoption.)

4. 1976–1977 school year – Beginning of series of metric programs on educational TV, continued development of metric awareness for all elements of Oregon society; development of metric system concepts for all aspects of school curriculum; adoption of textbooks. (Metric workshops help to prepare a cadre of local district metric education leaders. These people conduct metric in-service workshops for educators and metric orientations for noneducators.)

5. 1977–1978 school year – Repetition of metric television programs as needed; entrance of new textbooks into the classrooms. Continuation of metric in-service workshops for educators and metric orientations for noneducators presented by the cadre of Metric Education Leaders. For information, contact the Oregon Department of Education Metric Coordination Committee.

8. GLOSSARY

A minimal glossary is presented. The handbook was written with as little technical terminology as possible.

CONSERVATION — Preservation of length, area, volume or, mass when objects are changed by deformation, rearrangement, or partitioning; constancy of a quantity.

DIRECT MEASUREMENT — A procedure for directly counting the units of length, area, volume or mass associated with the corresponding attribute of an object, as opposed to obtaining a measure by an analogous measure which may involve a different object and a different attribute. One example of measuring indirectly is to determine temperature by noting the length of a thermometer's mercury column.

GRAM — The mass of 1 cm^3 of distilled water at 4°C.

INDIRECT MEASUREMENT — A procedure for determining the measure of one attribute of an object, such as its length, area, volume or mass, by measuring an attribute of a second object, also, a procedure for determining the measure of an attribute through the use of formulas and computational procedures. An example is using odometer revolutions to determine linear distance.

KILOGRAM — The basic unit of mass in the metric system. Based on a cylinder of platinum-iridium alloy kept by the International Bureau of Weights and Measures in Paris. The mass of one litre of distilled water at 4°C. Because the gram is quite small, the kilogram has become the commonly used basic unit of mass in the metric system.

LITRE — The basic unit of volume (capacity) in the metric system. Defined as one cubic decimetre. The millilitre and the cubic centimetre are both equivalent to one thousandth of a litre. The symbol for litre is a lower case, cursive or italic "*l*."

MASS — The terms "mass" and "weight" have been used as synonyms by some people. Mass is the amount of matter in an object and is measured in grams or submultiples or multiples thereof. Weight refers to the gravitational force on an object and is measured in newtons, a unit of force.

METRE — The basic unit of length in the metric system. Defined as 1 650 763.73 wave lengths in vacuum of the orange-red line of the spectrum of $krypton_{86}$. The symbol for metre is "m."

METRIC PREFIXES — In the metric system the value of the basic unit is changed by placing a prefix in front of it. The relationship of these quantities corresponds to the place values of the base ten numeration system.

	exa *	10^{18}
	peta *	10^{15}
	tera *	10^{12}
	giga *	10^{9}
	Mega*	10^{6}
Greek	kilo (thousands)	10^{3}

prefixes	hecto * (hundreds)	10^{2}
	deka *	10^{1}
Basic Unit	no prefix (one)	
	deci * (tenths)	10^{-1}
Latin	centi (hundredths)	10^{-2}
prefixes	milli (thousandths)	10^{-3}
	micro *	10^{-6}
	nano *	10^{-9}
	pico *	10^{-12}
	femto*	10^{-15}
	atto *	10^{-18}

*Not commonly used in everyday measurements.

QUALITATIVE COMPARISON Classifying (comparing) objects by noting the degree of a common property, for example, prettiness, hardness, texture, color, taste and smell. A premeasurement classification because these properties all deal with nonquantitative considerations.

QUANTITATIVE COMPARISON Classifying (comparing) objects by size.

SI Generally recognized symbol for the International System of Units (Le Systeme International d' Unites) which was developed by the tenth General Conference on Weights and Measures (CGPM) in 1954 and adopted by that body in 1960.

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